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New Data on Ichthyoplankton of the SouthWestern Pacific

andrei V. Suntsov
College of William and Mary - Virginia Institute of Marine Science

NEW DATA ON ICHTHYOPLANKTON OF THE SOUTH WESTERN PACIFIC

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by

Andrei V. Suntsov

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of
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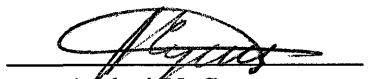

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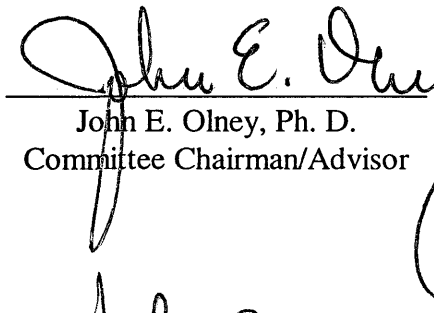
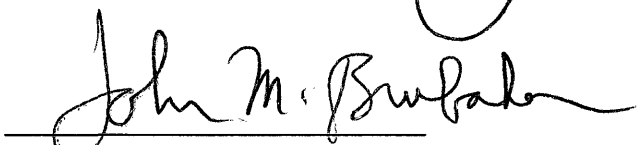
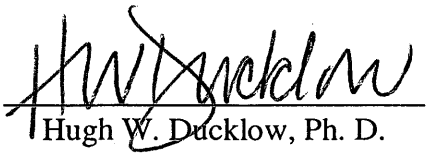


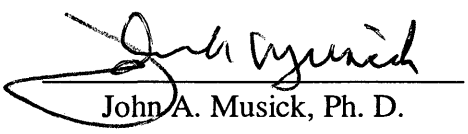
John E. Olney, Ph. D.
Committee Chairman/Advisor



John M. Brubaker, Ph. D.



Hugh W. Ducklow, Ph. D.



John A. Musick, Ph. D.

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PREFACE

Investigations of the zones of contact between waters of the South Pacific gyre and subantarctic waters have shown that the subantarctic region is remarkable for its high productivity and large concentrations of fish. Nevertheless, this region still remains the least studied area of the Pacific due to its remoteness. Assessment of the potential productivity of the subantarctic for future exploitation depends on knowledge of the basic rules governing the functioning of its ecosystems: physico-chemical properties of the water column, rates of biological processes, abundance and diversity of pelagic biota. The knowledge of what species comprise the particular ecosystem is prerequisitive for our insight in functioning this ecosystem in general, links between different trophic levels and inter- and intraspecific relationships.

Our understanding of the fish biology cannot be adequate without a good knowledge of the natural history and ecology of their larvae. Ecologically, larvae and adults are often completely different - they may occupy different habitats, consume different foods, and have entirely different behavioral patterns. The importance of taxonomic knowledge is fundamental in any biological research and cannot be overestimated. Marine fish larvae have evolved an enormous array of forms, morphological adaptations, and pigmentation patterns which can be used successfully in identifying particular species. Accurate identification of early life history stages of fish is a requisite for many studies in the fields of fisheries, oceanography and systematics.

The present study deals with ichthyoplankton collection obtained during 34th cruise of Russian R/V "Dmitrii Mendeleev" which took place during January-March 1986. The first two chapters of the proposed work are new descriptions of early life history stages of poorly known

species from subantarctic waters and waters of Subtropical Convergence - *Paradiplospinus antarcticus* Andriashev 1960 (Gempylidae) and *Astronesthes sp.* (Stomiidae). The third chapter explores the broad aspects of distribution of ichthyoplankton assemblages from different water masses of the south western Pacific.

CHAPTER 1

Larvae and juveniles of *Paradiplospinus antarcticus* Andriashev, 1960 (Gempylidae) from the subantarctic waters of the Pacific

INTRODUCTION

The trichiuroid family Gempylidae is a morphologically diverse group of marine fishes represented by 16 genera and 23 species (Nakamura and Parin, 1993). All species are oceanic epi- and mesopelagic or benthopelagic occurring at depths of about 150 to 2000 m. Gempylids are medium to large, fast-moving predators (exept *Diplospinus and Paradiplospinus*), with some species migrating upwards at night. Most species in this family are not commercially exploited, although some are occasionally caught as bycatch in tuna long-line fishery. Other species, such as *Thyrsites atun* and *Rexea solandri* play a significant role in fisheries (Nakamura and Parin, 1993).

The family is comprised of oviparous species, with planktonic eggs and larvae. Larvae of most gempylid genera are described except larvae of *Tongaichthys*, *Thyrsytoides* and *Rexichthys*. A number or researchers (Collette et.al, 1984; Nishikawa, 1987; Ozawa.1986) summarized the abundant literature on gempylid species.

There is no strict agreement about phylogenetic relationships among gempylid genera, although the systematic position of some species is quite established (Johnson,1986; Carpenter, 1995; Gago, 1995). The genus *Paradiplospinus*, is considered to be the most derived in the family, and is the sister group of *Diplospinus multistriatus*. Two species are described in this genus - *P. gracilis* and *P. antarcticus*. These two species have been often considered as synonymous, but were treated separately in the most recent and updated annotated list of trichiuroid fishes (Nakamura and Parin, 1993).

The majority of gempylid species is distributed throughout the world in tropical,

subtropical and warm temperate waters. However, *P. antarcticus* have circumpolar distribution in Antarctic and Subantarctic waters , thus being the ecologically aberrant representative of this family. *P. gracilis* has a rather restricted distribution, and known only off western South Africa. Little is known about the biology of *P. antarcticus.* Adults are considered to be epi- to mesopelagic or mesobenthopelagic near continental shelves and feed on krill, squid and myctophids (Permitin, 1969; Nakamura and Parin, 1993). Larvae of *P. antarcticus* are unknown, though larvae of its closely related species *P. gracilis* were described by Nishikawa (1984). Bussing (1965) described ontogenetic changes in juveniles of *P. antarcticus* specimens 32.2 - 410 mm SL in ranges (referred to as *P. gracilis*) collected in the Antarctic waters and off the shore of Chile.

As part of a larger investigation of larval and juvenile collection obtained during 34th cruise of Russian R/V " Dmitrii Mendeleev" this paper describes early development of *P. antarcticus.*

METHODS

Larvae and juveniles (n - 231) examined in this study were collected during a survey of the central and western subantarctic zones of the Pacific Ocean by the Russian R/V "Dmitrii Mendeleev" (December 16 1984 - April 15 1985). A detailed report on physical, chemical and biological data obtained during this cruise was provided by Vinogradov and Flint (1987). Most specimens were collected using an Isaaks-Kidd midwater trawl with a Samishev-Aseev modification (bag - 25m, mesh size - 5mm, caprone sieve No. 15 in the codend). Oblique tows were carried mostly in 200-0 m, but few tows were made in 1000-0 m. Details of the sampling gear and collections procedure were described by Becker and Evseenko (1987). Specimens were fixed in 4% formaldehyde, and later transferred to 70 % alcohol. No allowance was made for shrinkage or distortion in preservative.

Larvae and juveniles were examined using a stereo-microscope . Selected specimens were illustrated with the aid of camera lucida. Specimens were cleared and stained with alcian blue and alizarine red -S following Pothoff (1984) to facilitate meristic counts and examination of ossification patterns. Ossification was determined from the uptake of alizarine. Very light uptake (pink) of alizarine in a structure was considered as the beginning of ossification. Vertebral centra were counted as ossified only when a complete band of stain connected both neural and haemal spines. All cleared and stained specimens were maintained in solution of 50% glycerin with 1% KOH and thymol. Gill rakers were counted on the first arch.

Measurements were made on the left side using an ocular micrometer, and with

dial caliper in larger specimens. Measurements and their abbreviations were: standard length (SL)- distance from tip of snout to posterior end of the urostyle; snout length (SN) - distance from tip of snout to anterior margin of the orbit; head length (HL) -distance from tip of snout to the posterior margin of operculum; eye diameter (ED)- maximum diameter of fleshy eye socket; upper jaw length (UJL) - distance from tip of snout to posterior edge of maxilla; maximum body depth (H max) - vertical distance in front of pelvic spines; minimum body depth (H min) - vertical distance at caudal peduncle; predorsal length (PDL) - distance from the tip of snout to the beginning of dorsal fin; preanal length (PAL) - distance from the tip snout to the beginning of the anal fin; length of the spiny part of dorsal fin (SDFL); length of the soft ray part of the dorsal fin (RDFL); length of the anal fin (AFL).

MATERIALS EXAMINED

Larvae and juveniles

Paradiplospinus antarcticus Andriashev: 3008, n =33 specimens (12.0 - 82.0 mm SL), 48°44′S, 157° 49′W, 01/14/85; 3009, 69 (12.3 - 95.0), 46°50′S, 158°0 ′W, 01/16/85; 3010, 23 (13.8 - 69.0), 45°20′S, 157°33′W, 01/17/85; 3020, 1 (15.4), 45° 17' S, 157° 23.6' W, 01/18/85; 3042, 65 (13.1 - 82.0), 45°31′S, 157°43′W, 01/20-21/85; 3043, 2 (25.0; 132.0), 42°49′S, 158°12′W, 01/22-23/ 85; 3044, 3 (85.0 - 103.0), 41°32′S, 158°05′W, 01/23/85; 3045, 1 (132.0), 40°18′S, 157°58′W, 01/24/85; 3056, 17 (52.0 - 112.0), 43° 9.7' S, 125° 59.5' W, 02/16/85; 3059, 6 (36.5 -78.0), 44° 30.2' S, 125° 53.0' W, 02/17/85; 3065, 1 (21.0), 48° 31.7' S, 134° 58.2' W, 02/23/85, 3067, 10

(70.0 - 125.0), 44 ° 58.9 ' S, 134° 59.7' W.

Additional material included eight specimens of *P. antarcticus* 190-365 mm SL and eight specimens of *P. gracilis* 268-415 mm SL from the Russian ichthyological collections deposited at the Zoological Museum of Moscow State University (ZM MSU) and at the P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences (IO RAS). *P. antarcticus* : IO RAS without number (w/n), n = 4 specimens - 190, 205, 215 and 220 mm SL, RV"Mys Babushkin", 01.06.1980, 47°17' S, 155°46' W, bottom trawl, depth of catch 560-590 m; n = 3 specimens - 308, 350 and 365 mm SL, "Ghizhigha", 15.04.1978, 58°59'8"S, 42°14'9"W, midwater trawl; ZM MSU R 16294, n = 1 specimen - 345 mm SL, "Professor Mesyatsev", 24.04.1983, 47°22'8"S, 146°38'E. *Paradiplospinus gracilis*: n = 8 specimens - 268, 293, 322, 335, 350, 368, 410, and 415 mm SL, IO RAS (w/n) - no coordinates available (specimens collected off Namibia by S.V. Michailin).

GENERAL MORPHOLOGY AND MORPHOMETRICS

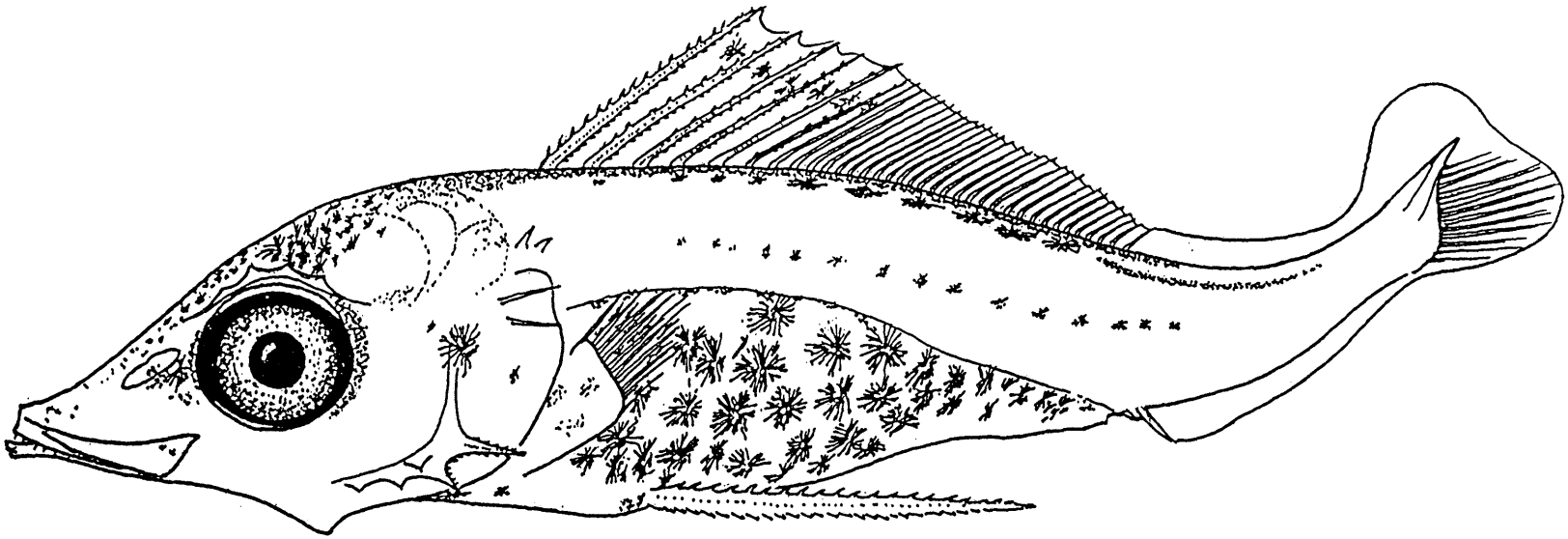
Body proportions of 12 specimens (12.2 - 91.1 mm) are summarized in Table 1. Early flexion larvae are characterized by a large compressed head (38.0-40.0 % SL) with a slightly convex upper profile. During development, the upper head profile becomes straight. The relative position of all fins remains unchanged during development. The distance between the anus and first anal spine slightly increases during growth. The smallest larvae have a deep, short and compressed body, a characteristic of all gempylid larvae. The body is deepest at the level of pelvic spines at all sizes. Body depth changes drastically during development from about 21% of SL in early flexion larvae, decreasing to 15.5% in postflexion larvae, and about 7.3-6.7% in larvae 67.0- 90.0 mm (Figs. 1a,b,c).

The eyes are large and round, almost equal in size to their orbits, and range from about 27.0-28.0% HL in the smallest larvae to 17.0-18.0% HL in postflexion specimens and juveniles. The mouth is large, with the posterior end of the maxilla almost reaching the level of anterior edge of orbit, its position remains unchanged during flexion. In juveniles, the upper jaw length slightly decreases due to an increase in snout length. Snout length is about 23% larger than orbit diameter in smallest larvae, becoming 50.0-55.0% bigger in juveniles (132.5 mm). The lower jaw remains prognate during development. A premaxillary symphysis is prominent especially in juveniles, giving the upper jaw a curved appearance.

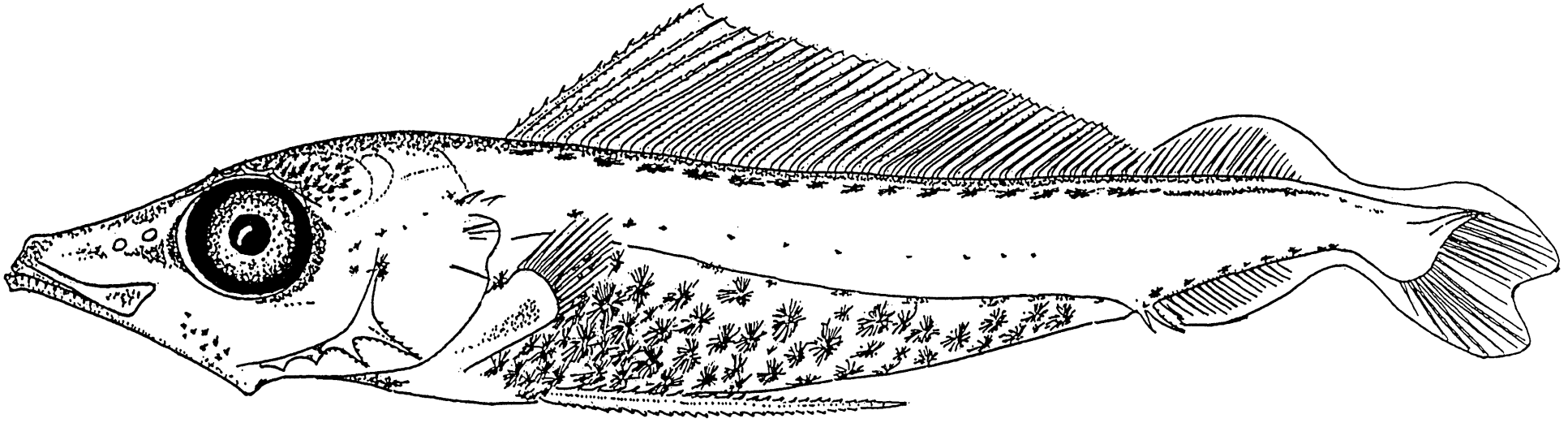
Table 1. Morphometric measurements of larvae and juveniles of *Paradiplospinus antarcticus* (in % of SL).

SL (mm)	SN	Hl	ED	UJL	Hmax	PDL	PAL	SDFL	RDFL	Hmin	AFL	pelvic spine
12.2	13.3	36.2	10.1	12.4	19.0	40.0	74.3	40.0	9.0	4.3	15.2	30.4
15.3	13.3	36.4	8.6	12.3	18.7	38.6	77.2	46.7	12.8	4.2	16.6	27.4
18.5	14.1	36.3	8.8	11.9	17.2	38.5	78.8	49.5	13.4	3.4	15.7	23.4
20.6	12.3	34.9	8.0	11.9	15.8	34.9	78.7	48.8	13.2	3.1	17.8	22.2
24.3	12.1	33.4	7.1	11.8	14.8	34.0	74.8	50.6	16.2	6.0	19.5	18.5
29.9	11.8	30.7	6.3	10.9	11.8	28.8	76.1	50.6	18.2	2.4	20.0	16.1
38.3	10.6	28.4	5.9	10.0	10.7	27.6	75.9	50.9	17.7	2.5	20.5	13.3
47.8	9.8	24.5	4.9	8.8	9.2	23.8	73.1	52.7	20.5	2.0	22.4	9.4
62.1	8.6	22.8	4.4	8.4	7.8	20.6	73.7	61.7	20.9	1.4	21.9	5.9
76.0	8.5	21.4	3.8	8.1	7.3	19.2	71.3	55.4	22.5	1.5	24.3	7.0
69.6	9.3	22.2	4.4	8.6	7.9	20.5	75.0	54.2	21.4	1.5	23.8	7.0
91.1	7.5	18.7	3.4	7.1	7.1	17.1	73.9	56.2	21.4	1.2	23.2	7.0

Fig. 1 *Paradiplospinus antarcticus*: a) 12.90 mm SL; b) 16.58 mm SL; c) 30.56 mm SL.



a



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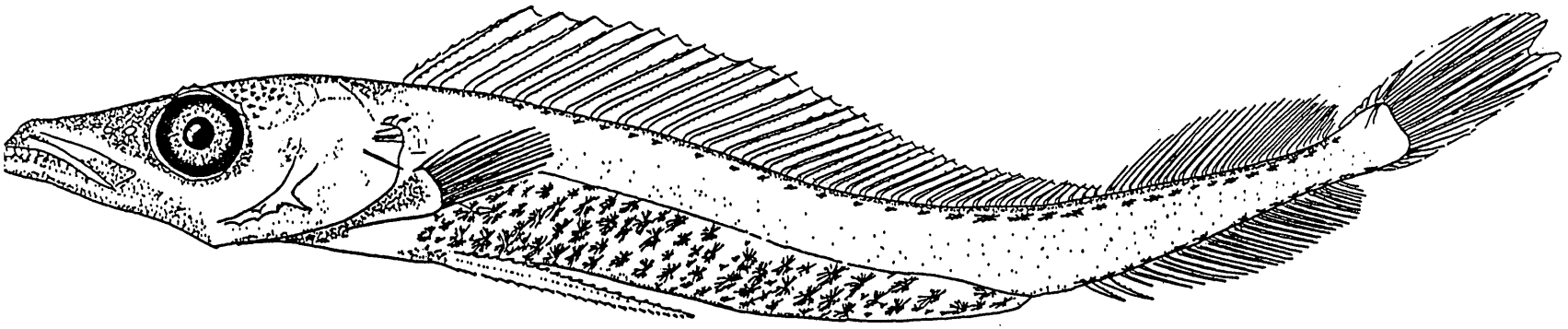


c

Head spines

The posterior margin of the preopercle bears four spines, the largest at its angle and three on the lower limb sequentially decreasing in size (Fig. 2). The two uppermost spines are serrated, and serrations also may develop partially in third spine in some flexion larvae. One small, laterally directed spine is situated on the lateral edge of the preopercle between the second and third spines. Preopercular spines, very distinct and conspicuous in small larvae, become less conspicuous during development due to extensive growth of preopercular bone (Fig. 2). In the largest juveniles, preopercular spines appear as serrations along preopercular edge.

Two small, stout, laterally directed spines are situated on the posttemporal and on the articular head of supracleithral bone. The postemporal spine bears minute serration. During flexion, three needle-like, clustered spines develop in the posterior upper part of operculum, slightly projecting from its margin. One similar spine is situated below these three spines. During development, the number of upper clustered spines increases to 5-6.

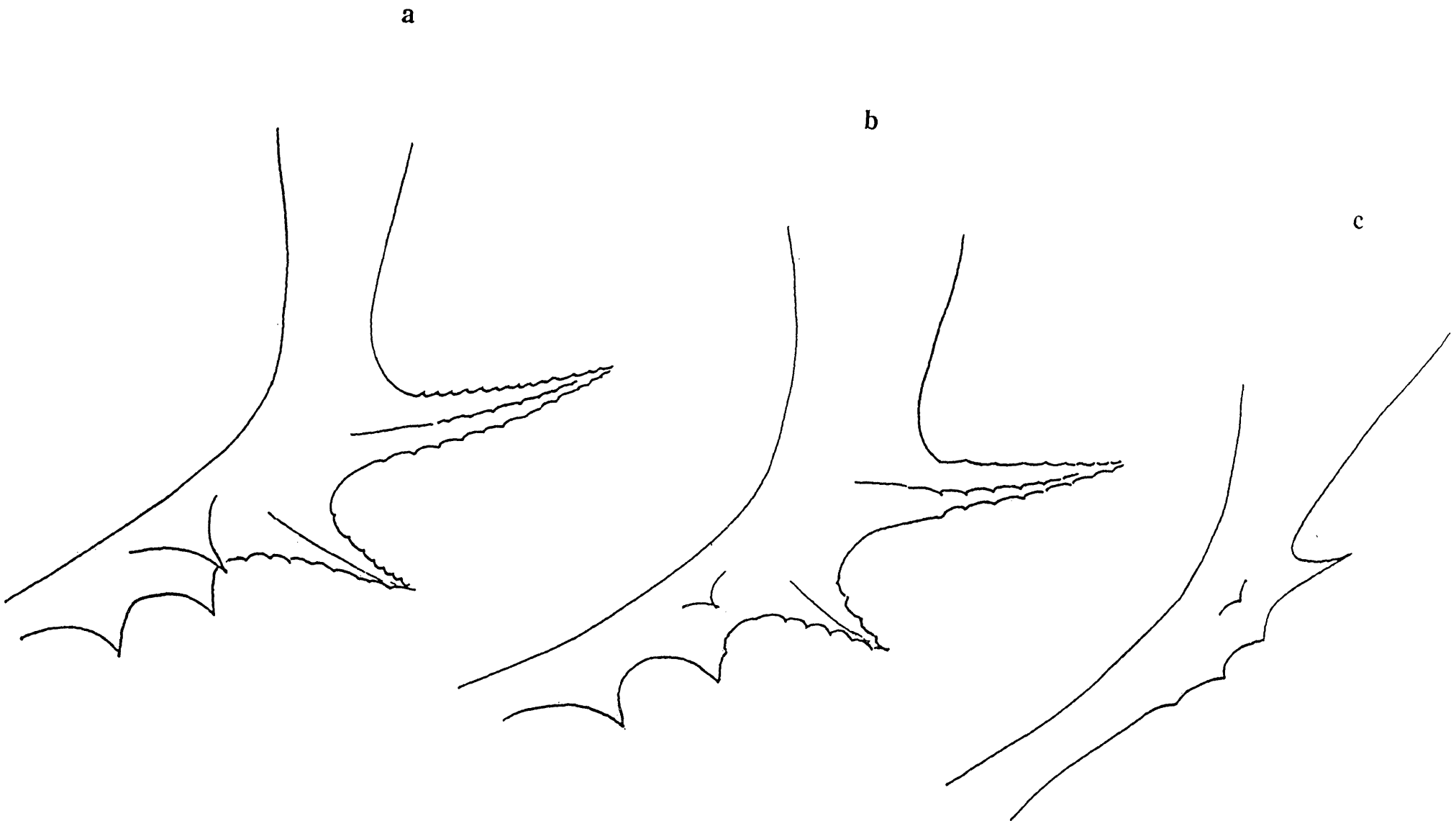
A conspicuous supraorbital ridge is situated above the each orbit, bearing 4-5 serrations. The ridge does not increase in size during growth and becomes less conspicuous and smoother in juveniles.

A large oval nostril opening is situated close to the anterior edge of the orbit. The constriction in the middle part of the nostril is discernable in early flexion larvae, and the anterior and posterior nasal openings are visible by 16.2-16.5 mm.

The lateral line is first discernable at 20.0-21.0 mm SL. It begins at the supracleithral spine, slopes slightly upward and then downward before leveling along the

Fig. 2 Ontogenetic changes in preopercular spines in *Paradiplospinus antarcticus*:

a) 12.80 mm SL; b) 30.89 mm SL; c) 75.20 mm SL.


a
b
c

body midline, and continues almost to the end of caudal peduncle. The lateral line consists of thin-walled short transparent tubes with oblique ends, and remains unossified even in the largest juveniles available.

Fin development

The spiny dorsal fin is high and steeply graduated, originating above the posttemporal spine. It is almost completely formed in early flexion larvae having 34-35 ossified spines. All dorsal-fin spines are V-shaped in cross section and bear small spinules along their anterior and lateral edges. Spinules on the anterior edges are present only on the first 10-12 spines, becoming restricted distally on the posterior spines. Only the first dorsal spine bears spinules along all its anterior edge. Ossification in the first dorsal fin is complete quite early, by 12.8-13.0 mm SL. Anterior spines are stout and long, reaching about 80% of the body depth. Ossification in second dorsal-fin rays begins at about 12.1 mm SL, almost simultaneously with ossification of the rays in the anal fin. Two dagger-shaped spines are present in the anal fin. The second spine forms in early flexion larvae following the appearance of the anteriormost spine. In larvae, the second spine is 0.25-2x longer than the first spine. Anal spines continue to grow until larvae reach 37-38 mm SL, thereafter increasing only in width. The formation of rays in both second dorsal and anal fins progress anteriorly and posteriorly. The ossification in these fins is complete almost simultaneously by 42-43 mm SL.

The pectoral-fin rays possess triangular elongated bases and are inserted at eye level . The formation of pectoral rays begins during preflexion and is complete by size

15.0-16.0 mm SL. Pectoral-fin rays are shorter than snout length and directed posterodorsally.

Each pelvic fin consists of a single hypertrophied spine, V-shaped in cross-section. The pelvic spines are situated below the posterior margin of the pectoral-fin base, and reach 26-27% SL in early flexion larvae (12-13 mm SL). During development, pelvic spines increase in width and become spatulate. Pelvic spines continue to grow until 25.0-27.0 mm SL, then becoming less conspicuous in juveniles. Pelvic spines bear small oblique spinules directed posteriorly along their edges.

The principal caudal rays are formed by 16.0-16.3 mm SL. The secondary caudal rays first begin to form as inferior rays at 13.5-14.0 mm SL. Superior secondary caudal rays begin to form at about 18.0 mm SL. The formation and ossification of secondary caudal rays is prolonged during development and continues until 73-75 mm SL. The caudal fin begins to fork at about 16.0 mm SL, and juveniles have well developed, forked caudal fin.

Dentition

In early flexion larvae minute teeth are present on the premaxillary. The formation of fangs on the premaxillary symphysis begins probably at late preflexion stage, since two small fangs are already formed in the smallest larvae available (12-13 mm SL). No teeth are present on the dentary except two anterolaterally directed tusks at the tip of the lower jaw. Minute teeth on the dentary begin to form at 12.5-12.6 mm SL. During development, a cluster of large fangs forms at the premaxillary symphysis with 2-3 large curved fangs in

the outer row and 3-4 movable fangs in the inner row on each side. With larval growth, numerous irregularly spaced and slightly curved teeth appear, some occuring in pairs, on dentary and premaxillary, with those on the dentary are more pronounced in later stages. In addition, small fangs are formed on each side of the of the anterior part of lower jaw in larvae 20-21 mm SL.

During development, a row of small teeth appears on each palatine at 17.5-18 mm SL. Two teeth first appear on the anterior part of the vomer at 16.0 mm SL. Later, two additional teeth are formed on the head of the vomer in some larvae, just posterior to those previously formed. Vomerine teeth are eventually lost during development, and juveniles have only uniserial teeth on the palatines.

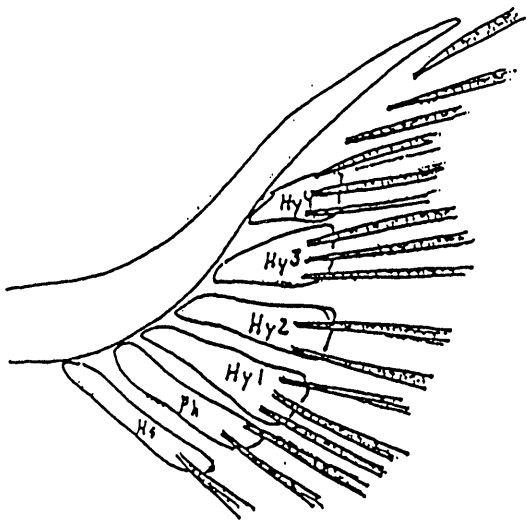
Ossification

Ossification sequences and meristic counts are summarized in Table 2. Size at hatching is unknown, and the smallest larva available (12.19 mm) was a flexion specimen. Thus, flexion probably begins in larvae 10.0-11,0 mm. The urostyle begins to ossify at 18.0-18.5 mm SL and flexion is complete by 21.0-22.0 mm SL. Ossification of vertebral centra progresses from anterior to posterior. Initially, vertebrae ossify in a saddle-like pattern, as described by Pothoff (1986) for other gempylids. By 32.0-33.0 mm SL ossification in most vertebrae and the urostyle is complete. In early flexion larvae (12.0 - 14.0 mm SL), the parhypural and three lower hypural plates are partly ossified. Ossification of all hypural elements is complete at 20.0-21.0 mm SL. Two epurals appear in cartilage at 19.0-20.0 mm SL and ossify at 22.2-42.7 mm SL (Fig. 3).

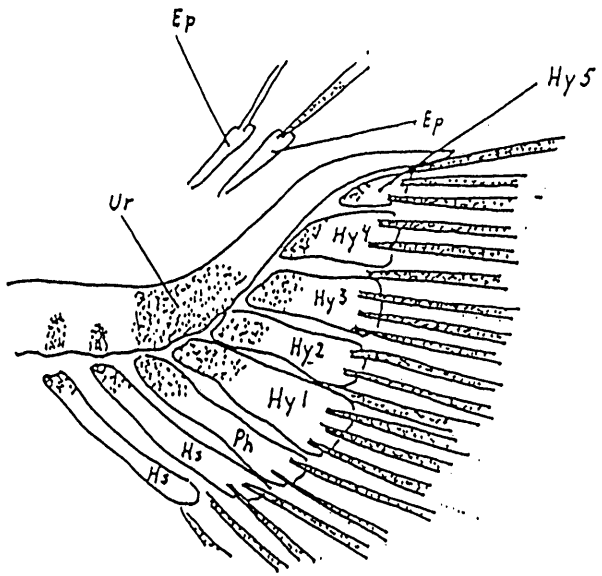
Table 2. Meristic counts for cleared and stained larvae and juveniles of *Paradiplospinus antarcticus*. Numbers in parentheses denote incomplete ossification.

SL (mm)	1st dorsal fin	2d dorsal fin	anal fin	pectoral fin	primary caudal		secondary caudal		teeth				gill rakers	vert.
					super.	infer.	super.	infer.	dentary	premax.	vomer	palatine		
12.5	33(2)	(5)	I,(7)	(10)	(4)	(8)	-	-	2/2	11/10	-	-	2+1+14	39(9)
12.8	38	(12)	II,(9)	(11)	(6)	(8)	-	-	4	4	-	-	3+1+15	42(8)
13.6	38	15(3)	II,9(5)	7(4)	4(5)	8	-	1	5/5	11/10	-	-	3+1+15	54(4)
16.3	39	17(4)	II,11(7)	13	7(2)	8	-	1	7/8	14/12	1/1	-	3+1+15	59(2)
18.5	38	24(1)	II,20(2)	13	9	8	1	2	9/10	/14	1/1	3/3	3+1+15	61(4)
19.8	39	25(2)	II,22(1)	13	9	8	1	2	14/10	/12	1/1	7/5	3+1+16	66
20.8	39	25(2)	II,20(4)	13	9	8	2(1)	2	12/11	9/	1/1		3+1+17	67
25.7	38	28(3)	II,25(2)	13	9	8	3(1)	3(1)	12/13	12/13	1/1	6/8	3+1+17	65
28.4	38	29(2)	II,25(2)	12/13	9	8	3(1)	4(1)	10/10	8/10	2/2	9/9	3+1+16	65
30.9	39	28(2)	II,25(2)	13	9	8	3(2)	3(1)	14/13	9/8	2/2	10/8	4+1+16	66
33.8	38	31(2)	II,28(1)	13	9	8	4(1)	4(1)	15/15	11/12	2/2	9/9	3+1+16	64
38.5	38	31(2)	II,28(1)	14	9	8	4(1)	4(1)	16/13	11/10	2/1	11/12	4+1+18	66
43.0	40	31(1)	II,28(1)	14	9	8	5(1)	5(1)	16/15	12/13	-/-	9/12	4+1+18	67
67.5	38	33	II,31	14	9	8	6(1)	5(1)	21/18	20/20	1/1	17/18	5+1+20	65
75.2	39	31	II,29	14	9	8	7	7	19/16	21/20	-/-	18/16	5+1+19	67

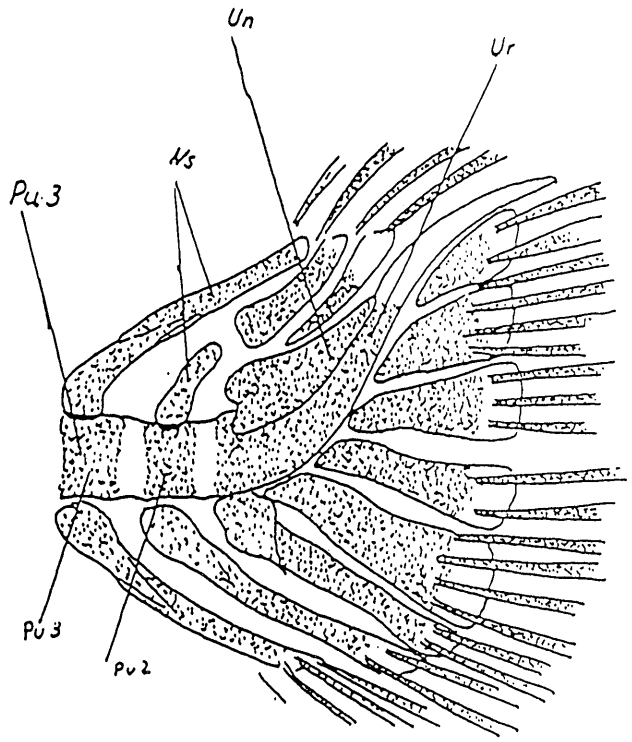
Fig. 3 Sequence of ossification in caudal skeleton of *Paradiplospinus antarcticus*: a) 17.7 mm SL; b) 19.5 mm SL; c) 29.0 mm SL. Hy - hypural bone; Hs - haemal spine; Ns - neural spine; Ph - parhypural bone; Pu - preural centrum; Ur - urostyle; Ep - epural bone.


Hy4
Hy3
Hy2
Hy1
Ph
Hs

a


Ep
Ep
Hy5
Ur
Hy4
Hy3
Hy2
Hy1
Ph
Hs
H3

b


Un
Ur
Hs
Pu3
Pu3
Pu2

c

Ossification of the pectoral girdle occurs late in development, although the scapula, coracoid and radials appear in cartilage in early flexion larvae. A long and slender ossified postcleithrum braces the abdominal walls. The pelvic girdle is ossified in smallest larvae available, and long epineurals are distinct in cleared and stained specimens.

Branchial region

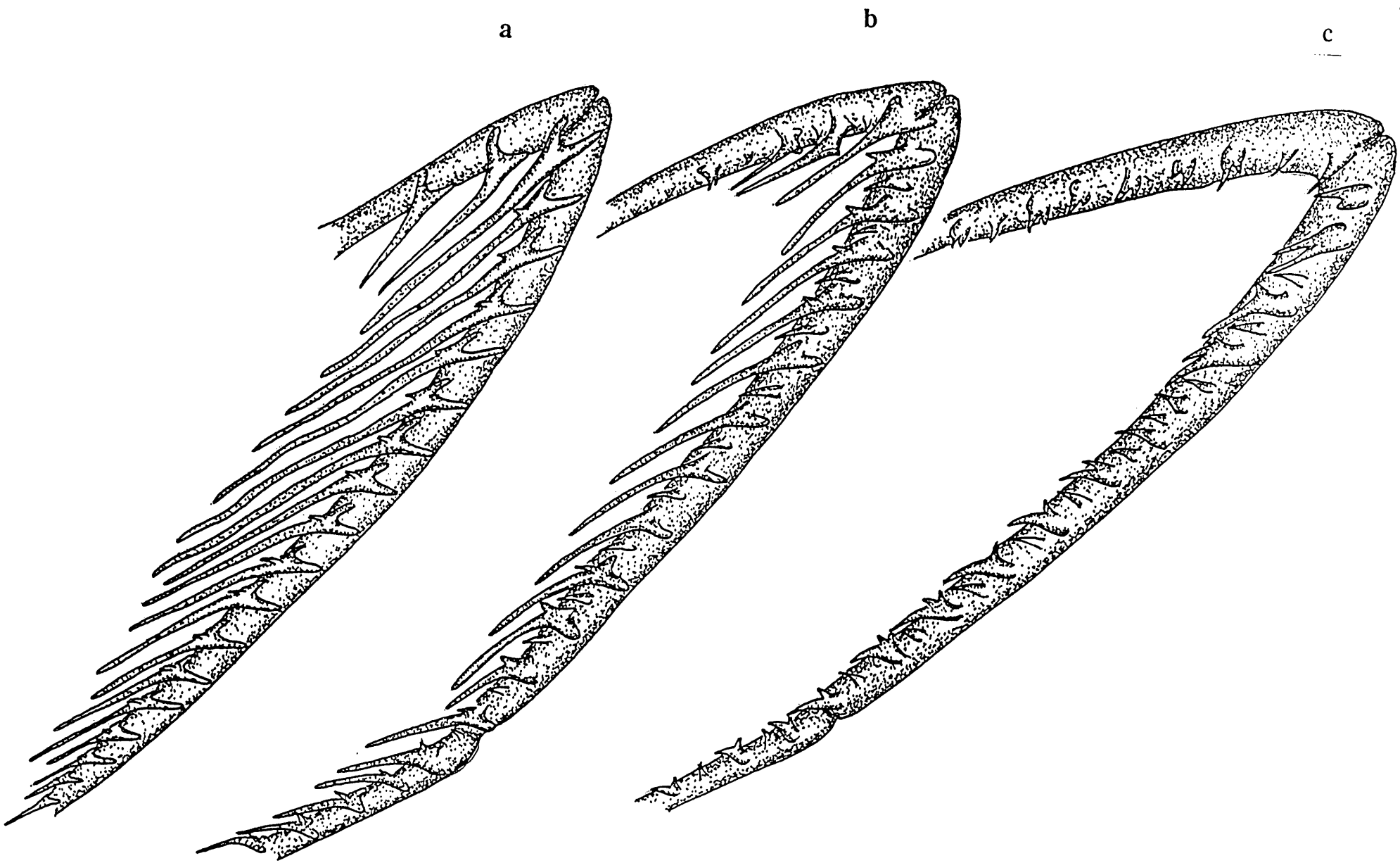
Branchial rays apparently appear very early in the development and are well formed and ossified in early flexion larvae. Long and slender gill rakers are well developed in larvae 12-13 mm, only slightly increasing in numbers with growth (Table 2). One spine is formed between each gill raker on the first and second gill arch in juveniles > 40 mm SL. The relative length of gill rakers decreases drastically during development, and resemble bi-tricuspidate spines in juveniles (Fig 4).

Pigmentation

Body

Early flexion larvae have numerous stellate external melanophores covering the peritoneal region. The dorsal midline is covered with dense pigment cells that increase in number during growth and spread posteriorly, eventually occupying all of the dorsal-fin base by the end of flexion. A row of large stellate melanophores is positioned below the spiny dorsal fin and becomes more conspicuous below the soft dorsal fin. During development, melanophores in this row undergo shrinkage and become embedded in the body wall, in largest juveniles (132.5 mm SL), appearing as small, sparsely situated dots below the dorsal midline. A similar row of stellate melanophores develops above the

Fig. 4 Ontogenetic changes in gill rakers on first gill arch in *Paradiplospinus antarcticus*: a) 13.0 mm SL; b) 75.2 mm SL; c) 132.3 mm SL.


a
b
c

anterior part of the base of the anal fin at 15-16 mm SL. Small pigment cells along the anal-fin base are also present, but this pigmentation is much less pronounced than that on dorsal midline. Small pigment cells are present anterior to pelvic spines and along the ventral body midline in the abdominal region. In smallest larvae (12-13 mm SL) a row of small melanophores, is situated along the body midline at mid-body. During development, these pigment cells are embedded in the body wall, becoming less conspicuous and only seen in cleared specimens. At 25-27 mm SL, numerous small, irregular melanophores are scattered on the posterior part of the body. Pigment is absent on the urostyle and caudal peduncle. This pigmentation expands anteriorly, covering most part of the body by 35-40 mm SL. In larger juveniles, these melanophores aggregate to form a regular pattern of 35-40 thin horizontal bars (not illustrated).

Head

Head pigmentation in early flexion larvae consists primarily of numerous stellate melanophores above the brain, on nape, melanophores behind the olfactory capsule, on the tip of the snout, and the gular region. A few stellate melanophores are present behind the eye. Numerous pigment cells are situated along the posterior margin of the orbit, a few are present on premaxillary, maxillary and dentary bones, and some can be seen basally and posteriorly on the neurocranium. In addition, a longitudinal line of pigment cells is present on the dentary. Melanophores are also present along the isthmus and in the branchial cavity. With growth, head pigmentation intensifies, with pigment cells covering most part of the snout, premaxillary and dentary bones. A few melanophores appear on the operculum and the junction between the glossohyal and hypohyal becomes heavily

pigmented. Pigment appears on the branchiostegal membrane at 21-22 mm SL, becoming distinct in larger juveniles on the first three rays. At the same size, pigment appears in the mouth near the premaxillary symphysis and the anterior lower jaw.

Fins

Fins are very lightly pigmented. The dorsal-fin membrane is damaged in most specimens, but the remains of pigment patches are visible between anterior dorsal spines in some early flexion larvae and larger specimens (22-23 mm SL). A few melanophores form on the lower caudal-fin rays at 34-35 mm SL, but remain sparse throughout development. Pectoral-fin lobes and rays are lightly pigmented.

COMPARATIVE NOTES

Paradiplospinus antarcticus and *P. gracilis* were recognized as valid species in a recent taxonomic treatment by Nakamura and Parin (1993). According to these authors, the two species have a significant overlap in dorsal- and anal-fin rays counts (D XXXVI - XXXIX, 28-34; A II,25-31 for *P. antarcticus* and D XXXV-XXXVIII, 26-30; A II, 24-29 for *P. gracilis*). The species differ in the number total vertebrae (64-67 for *P. antarcticus* and 60- 64 for *P. gracilis*) and in adult coloration (silvery white in *P. antarcticus* and brownish black in *P. gracilis*). Nakamura and Parin (1993) reported numbers of precaudal plus caudal vertebrae as: 37-39 + 26-28 for *P. antarcticus* and 35-38 + 23-26 for *P. gracilis*.

My data on precaudal plus caudal vertebrae number in these species (31-33 + 32-35 for *P. antarcticus* and 30-31 + 31-32 for *P. gracilis,* see Table 3) differ from those values. The counting procedure in their study followed that of the original description of *P. antarcticus* (Andriashev,1960) (Parin, N.V. pers. comm), with counts of caudal vertebrae starting at the level of the insertion of the first-anal spine. The procedure resulted in the inclusion of some precaudal vertebrae in the total number of caudal centra.

Larvae of *P. antarcticus* and *P. gracilis* have the following distinguishing features. Nishikawa (1984) described the development of *P. gracilis* based on eight larvae 6.4-23.4 mm SL caught off South Africa. According to his description, larvae of *P. gracilis* possess three spines on the outer edge of preoperculum with a serrated largest spine at the angle of preoperculum. Larvae of *P. antarcticus* have four spines

Table 3. Comparisons between vertebrae counts of adult specimens of *Paradiplospinus antarcticus and P.gracilis.*

Paradiplospinus antarcticus SL (mm)	vertebrae		*Paradiplospinus gracilis* SL (mm)	vertebrae	
	precaudal	caudal		precaudal	caudal
190.0	31	34	350.0	31	31
205.0	31	35	410.0	31	31
215.0	31	34	415.0	31	32
220.0	31	34	368.0	31	31
308.0	32	33	335.0	31	32
350.0	33	32	322.0	31	31
365.0	33	33	293.0	31	32
345.0	31	33	268.0	30	31

on the outer preopercular edge with serrations developing in the two upper ones. In addition, larvae of *P. gracilis* lack pigment on the lower jaw, the gular region and have fewer melanophores in the peritoneal region. Nishikawa's illustrations suggest that pigmentation in *P. gracilis* larvae consists of numerous small, unexpanded melanophores on the dorsal wall of the digestive tract. Apart from these differences, larvae of these species possess similar patterns of pigmentation including a row of melanophores along the dorsal- and anal-fin bases, a pigmented dorsal midline, melanophores along the body midline and pigmentation on the neurocranium.

DISTRIBUTION

Larvae and juveniles of *P. antarcticus* described in this study were caught exclusively in subantarctic waters (Fig. 5). This observation is in a good agreement with the findings of Vinogradov and Flint (1986), that subantarctic waters represent a separate biogeographical domain that does not a mix with subtropical and antarctic communities. The majority of larvae and juveniles (82 %) were collected at stations 3008, 3009, 3010 and 3042 on the western-most transect (158°W). A deployment of the Isaaks-Kidd midwater trawl on the second (125°W) and third transects (135°W) captured 18 juveniles (mean SL 78.0 mm) and 11 larvae (mean SL 89.0 mm). Most of the remaining larvae caught at other stations were 10-50 mm SL (Fig. 6). Among all samples, a distinct trend in decreasing number of larvae and increasing mean standard length in the direction from south to north is apparent (Fig. 7, 8). In the meridional direction (from west to east), an increase in mean length and decrease in abundance was observed. However, due to differences in sampling efforts on all three transects, details of the distribution of early life history stages of *P. antarcticus* in subantarctic waters remain unclear.

The lack of intensive ichthyoplankton collections in southern portion of subantarctic waters on stations 3007, 3060, 3061, 3064 and 3066 makes it difficult to define the lower limit of distribution of *P. antarcticus* larvae in subantarctic waters. However, larvae are probably quite rare south of 48°S. On the southernmost station 3065, only one larva was captured.

The collection of juveniles of this species is in agreement with previous studies

Fig. 5 Cruise track and station locations: 1- cruise route and stations; 2- southern tropical convergence; 3 - front of the southern boundary of the STFZ; 4- subantarctic front; 5 - antarctic front; STFZ - subtropical frontal zone; APFZ - antarctic polar front zone. ● - stations with *Paradiplospinus antarcticus* larvae and juveniles.

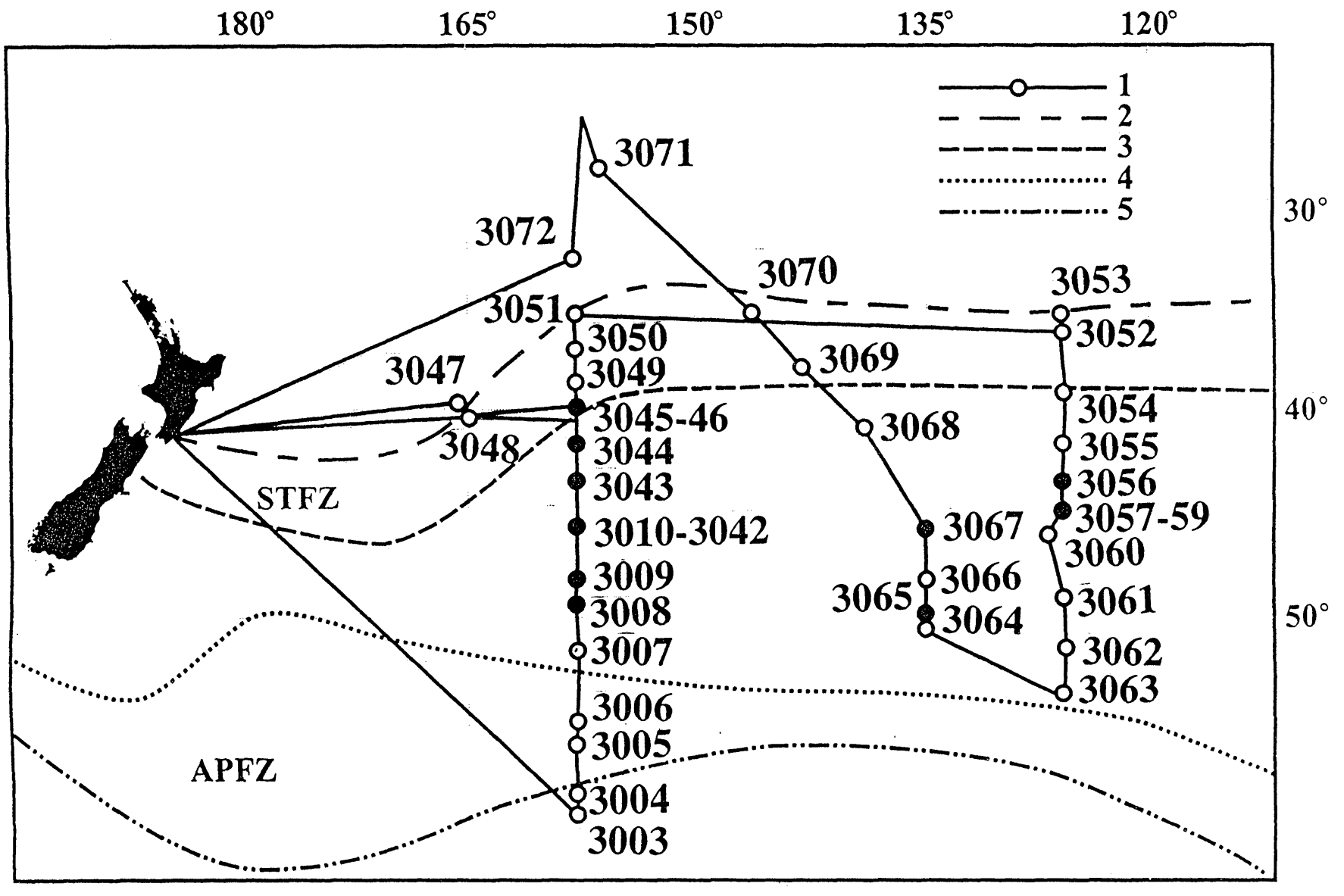

180°
165°
150°
135°
120°
30°
40°
50°
1
2
3
4
5
3071
3072
3070
3053
3051
3052
3050
3049
3069
3047
3054
3045-46
3068
3048
3055
3044
3056
3043
3057-59
STFZ
3067
3010-3042
3060
3009
3066
3065
3061
3008
3064
3007
3062
3063
3006
3005
APFZ
3004
3003

Fig. 6 Length frequency of all specimens of *Paradiplospinus antarcticus* caught during 34th cruise of R/V " Dmitrii Mendeleev".

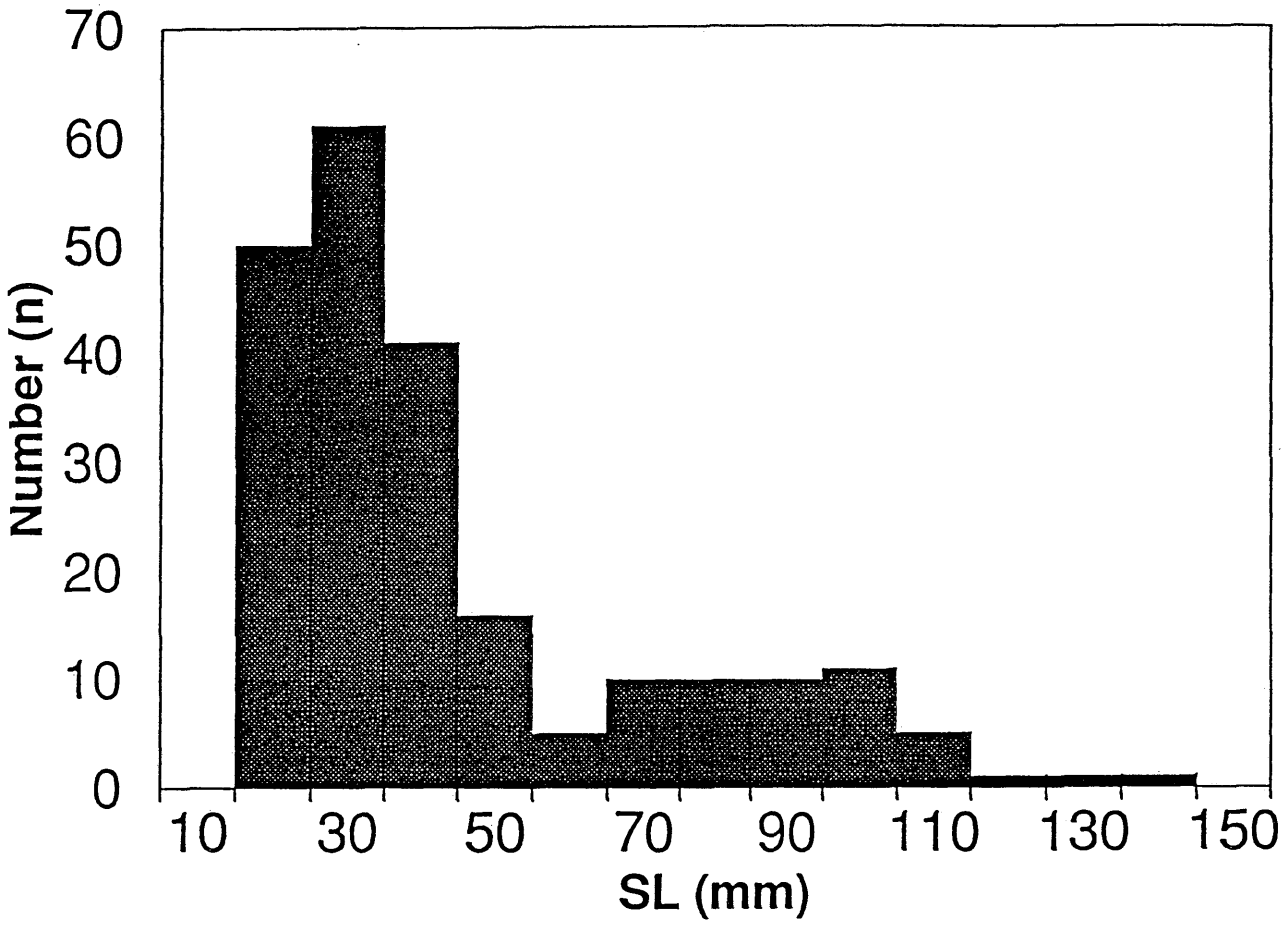

70
60
50
40
30
20
10
0
Number (n)
10
30
50
70
90
110
130
150
SL (mm)

Fig. 7 Size distribution of larvae and juveniles of *Paradiplospinus antarcticus*.

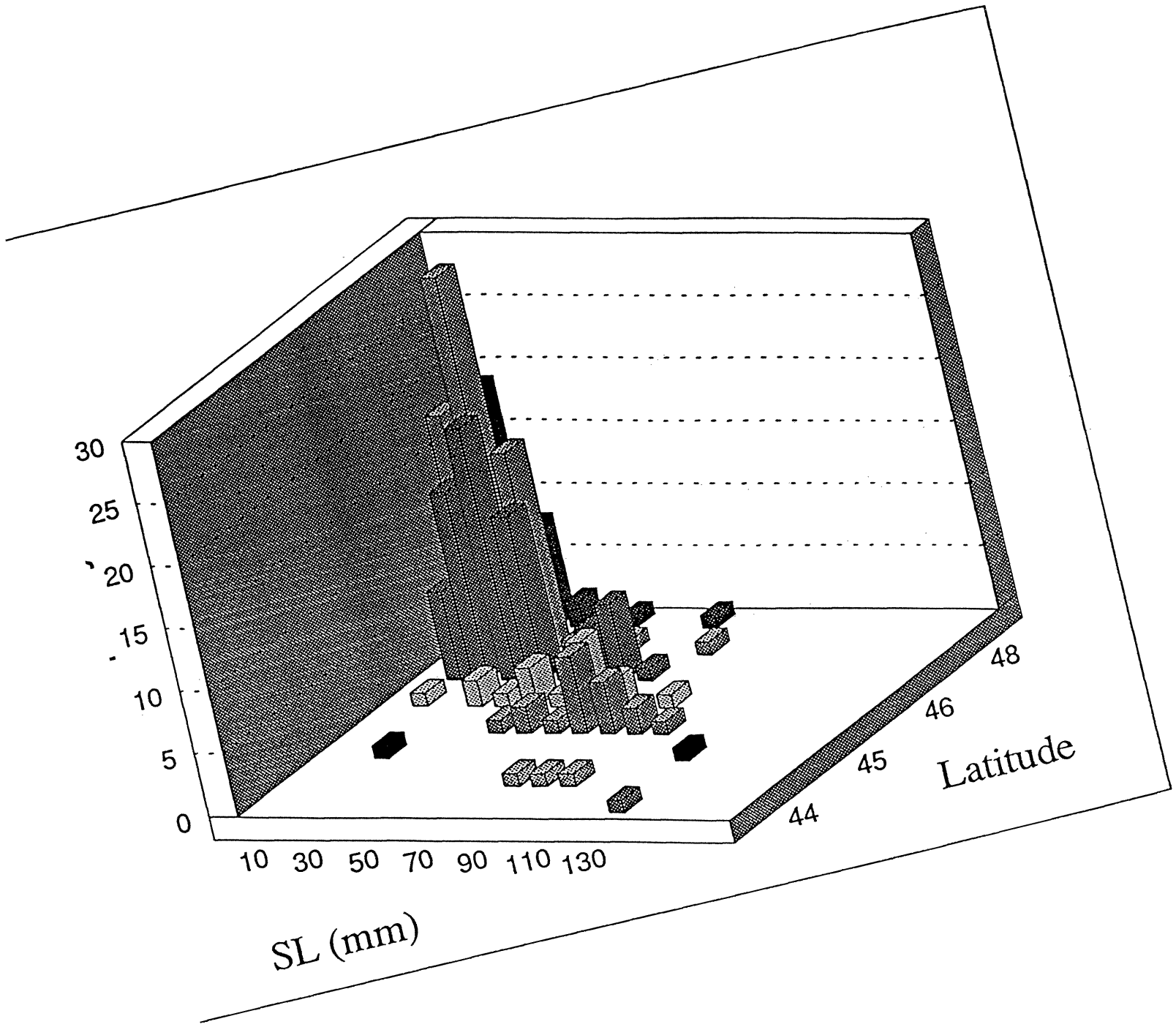
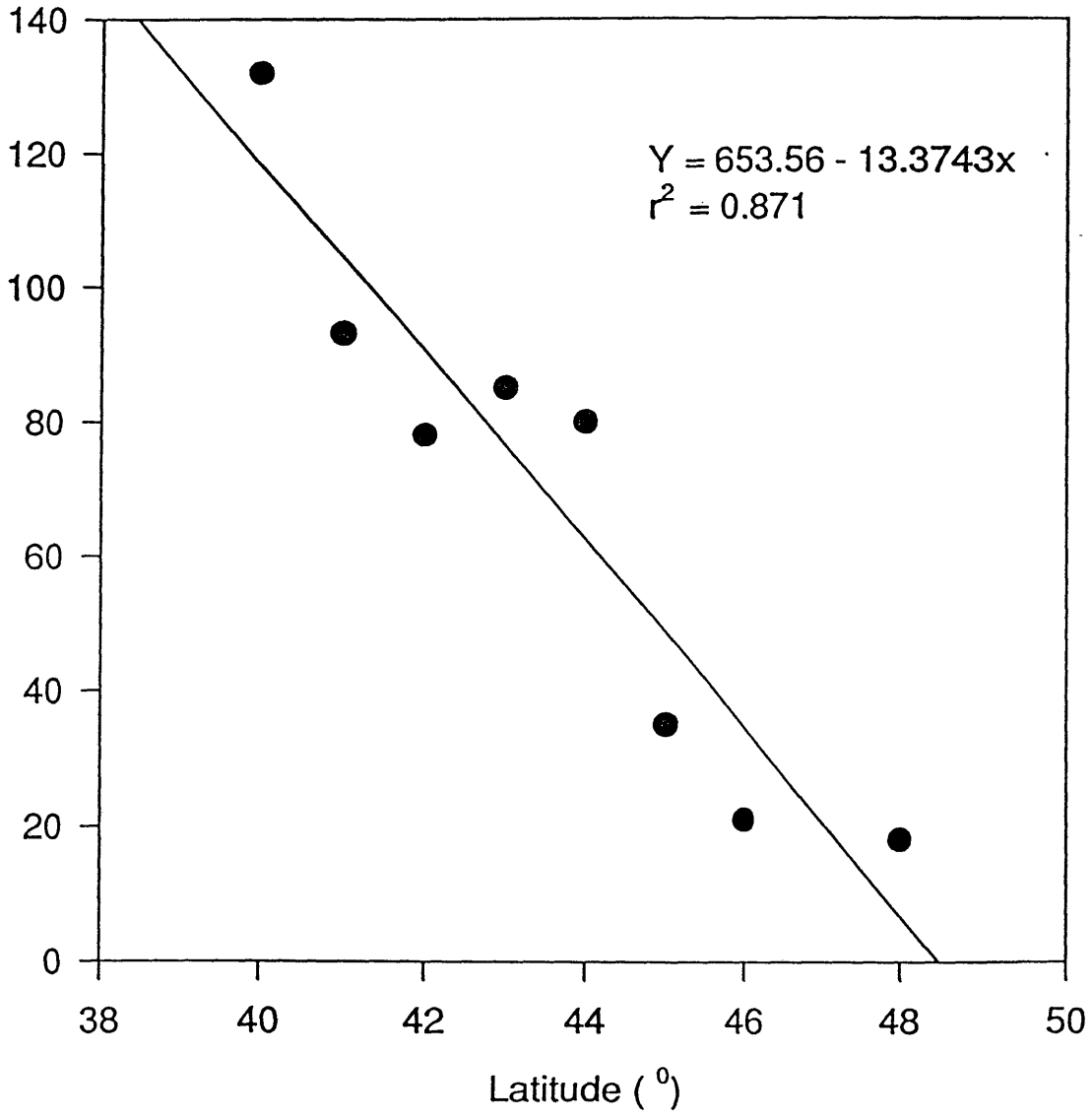

30
25
20
15
10
5
0
10 30 50 70 90 110 130
SL (mm)
44
45
46
48
Latitude

Fig. 8 Regression plot of mean SL of larvae and juveniles of *Paradiplospinus antarcticus* vs. sampling location.


140
120
100
80
60
40
20
0
38
40
42
44
46
48
50
Y = 653.56 - 13.3743x
r2 = 0.871
Latitude (0)

(Bussing, 1965; Permitin, 1969) in which larvae and juveniles were reported only north of the Antarctic convergence in subantarctic waters. Bussing (1965) hypothesized that juveniles of this species inhabit deeper waters than adults, but the "Eltanin" collections described in his study resulted from deployment of nonclosing nets. The majority of larvae and juveniles collected in the present study were caught in 0-200 m surface waters tows. Permitin (1969) proposed that spawning of *P. antarcticus* occurs in the deep subantarctic waters, and that adult fishes spend most of their life cycle in the productive antarctic waters. Since the smallest larvae taken in the present study occurred in the southern part of subantarctic waters on the transect 158°W, it is likely that spawning occurs in the southern part of subantarctic waters. The limited data on ichthyoplankton in this area precludes more detailed descriptions of the distribution and abundance of early life history stages of this species.

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CHAPTER 2

Development of *Astronesthes sp.* from the Subtropical Convergence region of the south western Pacific

INTRODUCTION

The stomiiform subfamily Astronesthinae (*sensu* Fink, 1985) contains more than 30 meso- and mesobenthopelagic, moderate-sized, predatory species distributed in all tropical and temperate regions of the world ocean. Six genera, *Astronesthes*, *Neonesthes*, *Rhadinesthes*, *Heterophotus*, *Borostomias* and the recently described *Eupogonesthes* (Parin and Borodulina, 1993) are currently recognized. The genus *Astronesthes* is the most diverse, containing about 30 species,with many new species descriptions published during recent years (Gibbs and McKinney, 1988; Parin and Borodulina, 1995; Parin and Borodulina, 1997). However, with no recent revision, the systematics and taxonomy of this subfamily remain obscure.

Our knowledge of the early ontogeny of this group of fishes lags far behind that which is known for adults, primarily due to difficulties in identification of eggs and larvae. With significant overlap in meristics, taxonomy of adults is based primarily on characters such as the number of photophores and morphology of the chin barbel that are not developed in larvae. Thus, despite the fact that astronesthine larvae are quite common in oceanic ichthyoplankton collections, most of them are usually identified only to the family or generic level (Belyanina, 1982; Kawaguchi and Moser, 1984) with only few descriptions on species level available (Whitley, 1941; Pertseva-Ostroumova and Rass, 1973; Evseenko and Suntsov, 1995; Okyiama, 1988, Moser, 1996a). Astronesthines are presumed to be oviparous, but their planktonic eggs have not been described. To date, no detailed information is available on metamorphosis,

osteological development, changes in body proportions and pigmentation or other aspects of early ontogeny for this subfamily.

During the 34th cruise of the Russian RV "Dmitrii Mendeleev", a relatively large number of astronestine larvae of one kind were caught in the region of Southern Subtropical Convergence. The availability of metamorphosing specimens with photophore formation in some series and high myomere counts allowed the identification of these larvae to one of the high-count species of *Astronesthes* from the Southern Subtropical Convergence described by Gibbs and McKinney (1988).

METHODS

Larvae and metamorphosing specimens (n = 53) examined in this study were collected during a survey of the central and western subantarctic zones of the Pacific Ocean by the Russian R/V "Dmitrii Mendeleev" (December 16 1984 - April 15 1985). A detailed report on physical, chemical and biological data obtained during this cruise was provided by Vinogradov and Flint (1987). Specimens were collected using Isaaks-Kidd midwater trawl with a Samishev-Aseev modification (bag - 25m, mesh size - 5mm, caprone sieve No. 15 in the codend). Oblique tows were carried mostly in 200-0 m, but a few tows were made in 1000-0 m. Details of the sampling gear and collection procedure were described by Becker and Evseenko (1987). Specimens were fixed in 4% formaldehyde, and later transfered to 70% alcohol. No allowance was made for shrinkage or distortion of larvae in preservatives.

Larvae and metamorphosing specimens were examined using a stereomicroscope, and selected specimens were illustrated with the aid of camera lucida. Specimens were cleared and stained with alcian blue and alizarin red -S following Pothoff (1984) to facilitate meristic counts and to examine ossification patterns. Ossification was determined from the uptake of alizarin and weak positive reactions of alizarin in a structure (observed as a light pink color), were interpreted as the onset of ossification. All cleared and stained specimens were maintained in solution of 50% glycerin with 1% KOH and thymol.

Measurements were made on the left side using ocular micrometer, and with dial caliper in larger specimens. Measurements and their abbreviations were: standard

length (SL)- distance from tip of snout to posterior end of the urostyle; snout length (SN) - distance from tip of snout to anterior margin of the orbit; head length (HL) - distance from tip of snout to the posterior margin of operculum; upper jaw length (UJL) - distance from tip of snout to posterior edge of maxilla; maximum body depth (H max) - vertical distance in front of pelvic spines; minimum body depth (H min) - vertical distance at caudal peduncule; predorsal length (PDL) - distance from the tip of snout to the beginning of dorsal fin; preanal length (PAL) - distance from the tip snout to the beginning of the anal fin; length of the anal fin (AFL). Photophore abrreviations were: AC - ventral series, from behind level of last VA photophore to caudal fin base; BRP - photophores on branchiostegal membrane; PV - ventral series, from pectoral - fin base to pelvic-fin insertion; VAV - ventral series, from behind pelvic-fin insertion to anal-fin base before AC series. Gill rakers were counted on the first arch.

Materials examined

Astronesthes sp. : 3049, 42 specimens (19.0 - 48.0 mm SL), 39°00'S; 158°01' W, 02/04-05/85; 3050, 4 (24.0 - 44), 37°29.2' S, 157°59.3'W, 02/05/85; 3051, 4 (44.0 - 46.5), 35° 08.4' S, 157°59.1' W, 02/06-07/85; 3052, 3 (40.0-47.0), 38°02.0' S, 126°10.0' W, 02/12-13/85.

RESULTS

General morphology

A summary of body proportions of 16 specimens is presented in Table 1. Size at hatching is unknown, and the smallest larva in my collection was 18.0 mm SL. Small larvae are slender, with bodies that are nearly circular in cross-section. Maximum body depth (6.1-6.6 % SL) occurs at mid-body anterior to the dorsal fin. The body becomes slightly deeper and more compressed during development, with Hmax reaching 8.1-8.8 % SL in larvae 45-47 mm. Larvae reach very large size (46.0-47.0 mm SL) before metamorphosis (Fig.1).

Gut

The hypaxial muscles do not completely embrace the abdominal cavity. Thus, the gut can be clearly seen through the transparent body wall. The straight gut is deflected away from the body just anterior to the anal fin, and forms a trailing gut that reaches a length of 14-16%SL in small larvae. The development of the trailing gut intensifies during larval growth, increasing to 27-33% SL in larvae 40-47 mm, and reaches a maximum relative length in specimens 45-47mm SL. The main part of the gut can be clearly seen in larvae during development since it is surrounded by a transparent membrane and partially because the hypaxials remain under-developed and transparent even in the largest larvae (45-47mm SL). With the development of hypaxials the gut becomes eventually integrated within the body walls.

Table 1. Morphometric measurements of larvae and metamorphosing specimens of *Astronestes sp.* Values are reported as % of standard length. n is number of specimens. Other abbreviations are defined in text.

SL (mm)	n	PDL	PAL	HL	SN	UJL	Hmax	Hmin	DFL	AFL	Length of trailing gut
18.0-21.0	3	65.5-69.4	83.3-85.0	13.3-14.4	4.2-4.5	4.2-4.5	6.1-6.6	2.7-3.3	7.2-7.6	7.1-7.5	14.2
23.0-28.0	3	66.1-67.4	83.9-83.9	11.8-13.5	3.9-4.3	5.3-5.5	6.7-7.8	3.0-3.6	7.4-8.2	7.8-8.6	-
30.0-34.0	3	62.1-64.7	81.2-83.3	11.7-12.5	3.9-4.7	5.5-6.2	6.5-7.8	3.3-3.7	8.5-9.3	8.2-9.3	16.6-18.7
36.0-40.0	3	62.5-66.6	75.5-78.9	10.7-11.6	3.2-3.8	5.0-5.5	7.1-7.5	3.4-3.7	9.7-10.0	10.5-12.5	26.2
44.0-47.0	4	63.1-63.8	72.2-82.9	9.8-10.8	3.2-3.4	5.5-6.3	8.1-8.8	4.0-4.7	8.8-10.6	10.9-11.7	27.7-32.3

Fig. 1. Development of *Astronesthes sp.* : a) 18.0 mm; b) 29.0 mm; c) 47.0 mm; d) 44.0 mm.

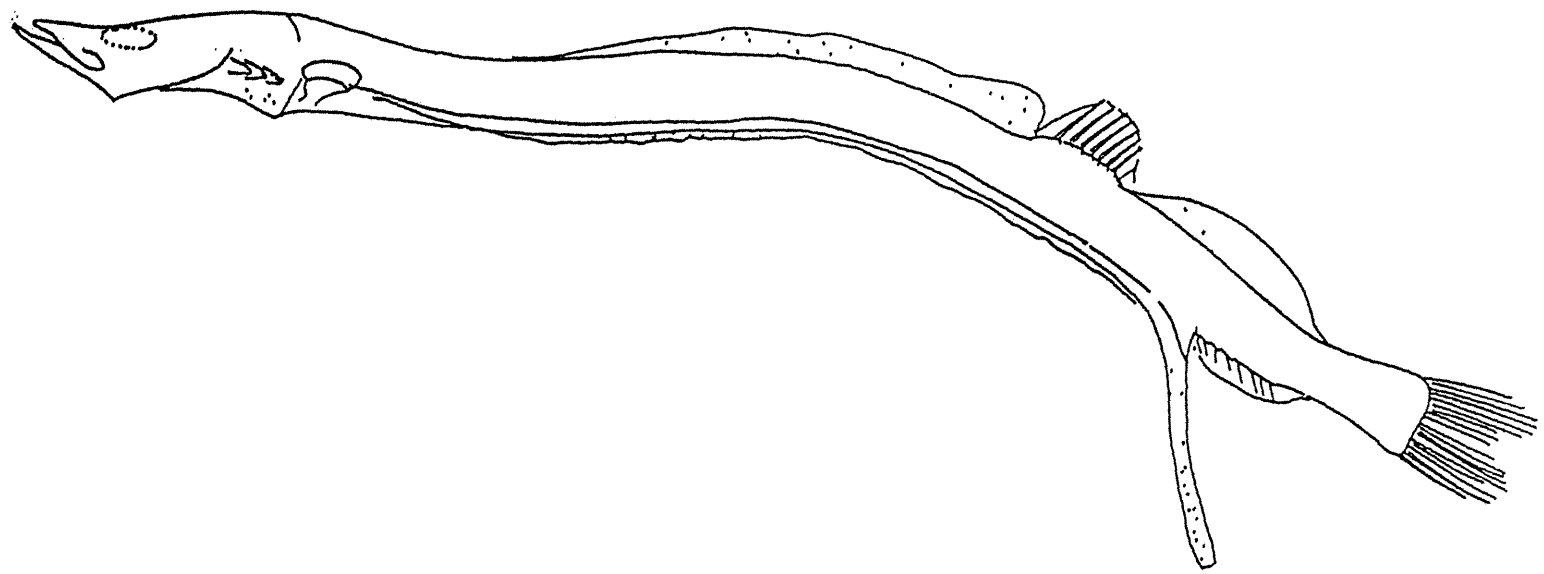


Fig. 1a

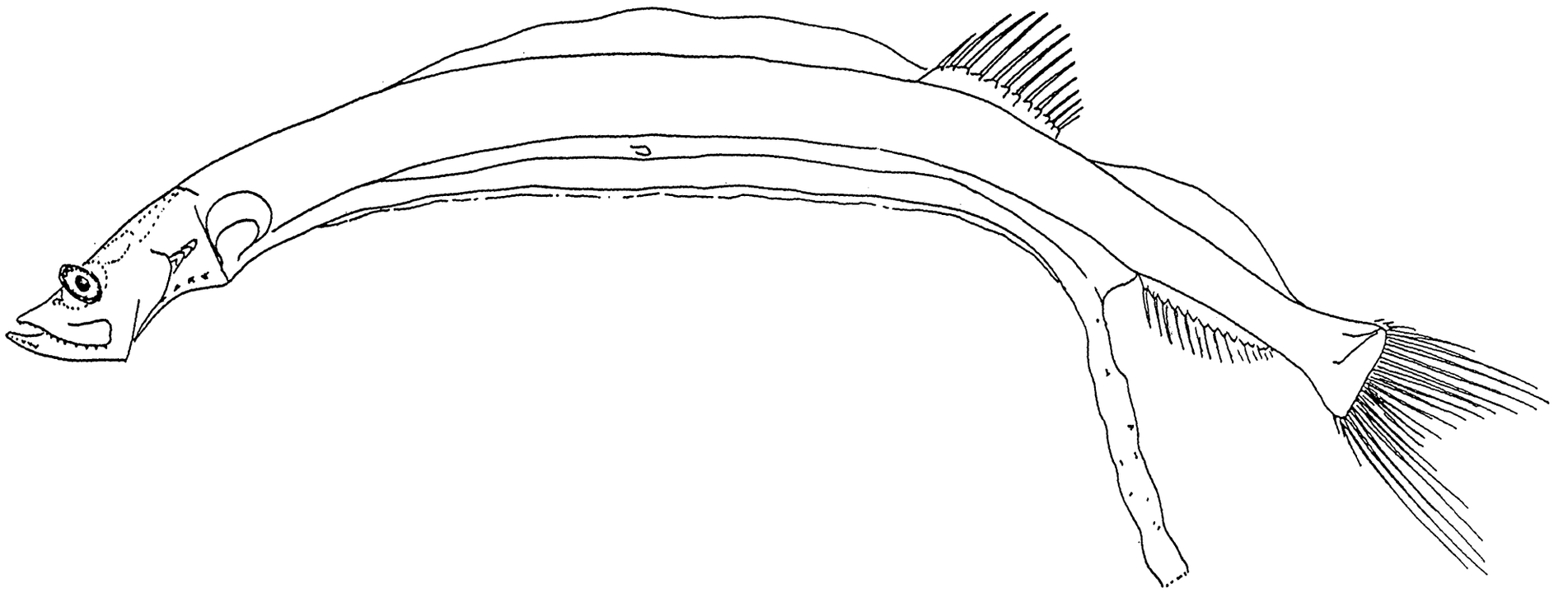


Fig. 1b

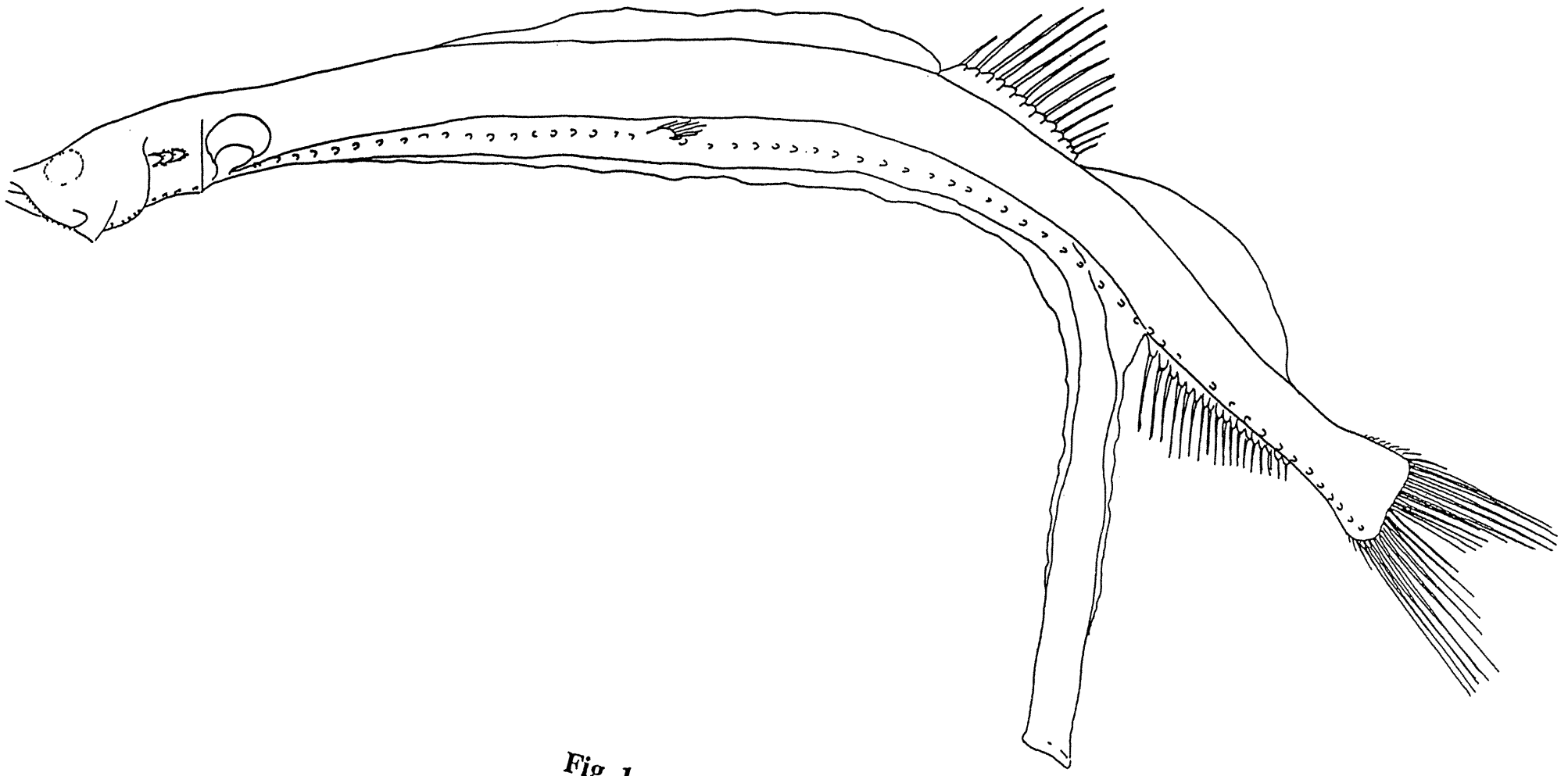


Fig. 1c

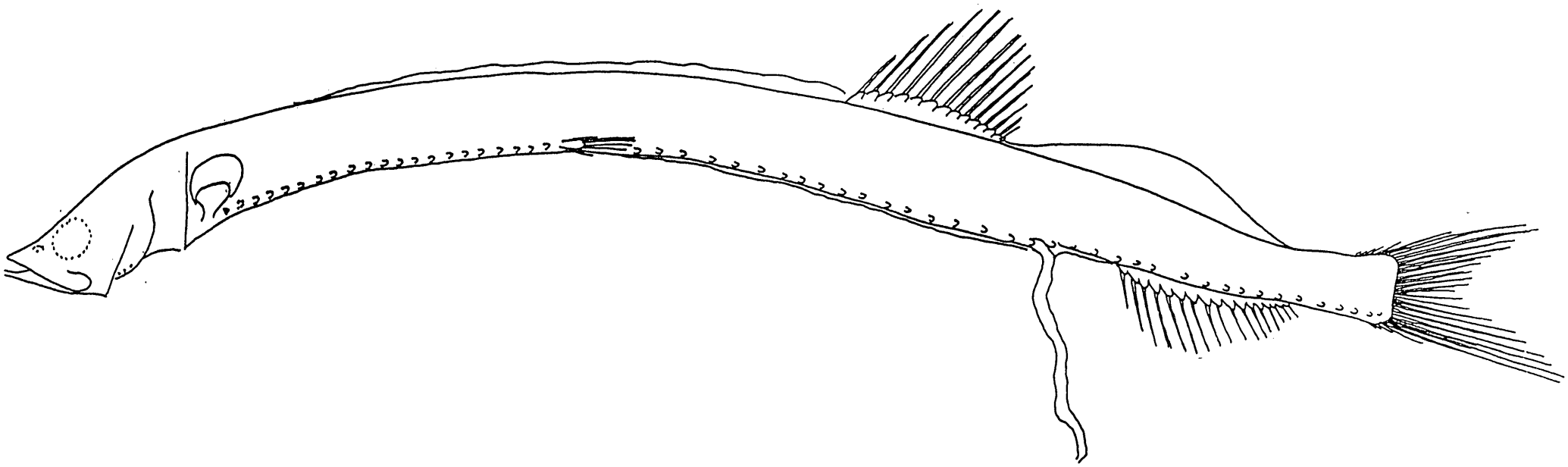


Fig. 1d

Head

The head is small and its relative length decreases gradually from 13-14% SL in larvae 18-20 mm to 9.8-10.8 % SL in larvae 40-45 mm. The orbits are situated very close to the upper head profile. Only one specimen (29 mm SL) in the collection possesed intact eyes. On this specimen, the eyes are oblong, slightly stalked and somewhat smaller than the orbits. The upper head profile is slightly convex . The snout is short and spatulated in shape, slightly decreasing from 30-33% of head length in smallest larvae to 27-28% of head length in metamorphosing specimens. The mouth size also increases during larval development. The posterior portion of the maxilla extends to the anterior margin of orbit in larvae 18-20 mm SL and increases in length to the posterior margin of orbit in metamorphosing specimens. The lower jaw protrudes and remains prognate during development. The operculum is small and posterior parts of the gill arches are exposed. Olfactory pits are oval, quite large, placed horizontally on the flat snout, and conspicuous only in large larvae. The chin barbel observed in adults is not developed in the material at hand.

Fins

Both dorsal (D) and anal (A) fins are already well developed in smallest larvae, although meristic data (Tables 1-3) show that adult complement for D&A are not attained until ~ 24 mm. The fleshy bases of both fins are very conspicuous and protrude well above the body profile. The dorsal fin inserts at myomere 36-37 and extends to myomere 41- 42. The anal fin inserts at myomere 49-50 and extends to myomere 57 - 58. The caudal fin is forked with lower lobe slightly larger than the

Table 2. Meristic data for cleared and stained larvae and metamorphosing specimens of *Astronesthes sp.*

SL (mm)	Gill rakers	D	A	P	V	Caudal fin	Teeth		
							premaxillary	maxillary	dental
18.0-21.0	0+0-1+9-10	8-12	8-12	-	-	(0-1)-10+9-0	-	11-12	6-7
24.0-29.0	0-1+1+10-14	12-14	12-16	-	-	(2-3)-10+9-(1-2)	3	12-13	5-7
30.0-32.0	1-2+1+13-16	13-14	12-16	-	-	(3-4)-10+9-(2-3)	3	12-13	5-6
34.0-41.0	2-3+1+14-16	13-14	16-17	0-3	0-7	(4-7)-10+9-(3-4)	3	12-13	5-6
43.0-47.0	3+1+14-16	13-14	17-18	4-5	7	(8-9)-10+9-(5-6)	3	12-13	5-6

Table 3. Comparison of photophore counts of high-count species of *Astronesthes* from the Southern Subtropical Convergence (data from Gibbs and McKinney,1988 and this study)

Species	PV					VAV							AC					BRP				
	19	20	21	22	23	22	23	24	25	26	27	28	11	12	13	14	15	19	20	21	22	23
A.kreffti	2	5	4						2	5	4			1	9	1				5	5	3
A.psychrolutes		7	11	6	1	1	2	8	9	4				4	15	3	2	6	9	11	1	
A.spatulifer	8	10	1							8	11	1	1	12	7				9	10		
Larvae in present study		2	2							3	1			4					4			

upper one. Pelvic fins are first seen as buds below 24-25 myomers in larvae 27-28 mm SL. Pectoral fins are pedunculate and fan shaped, placed close to the ventral body profile. The formation of pectoral fins is rather precocious, and appearing at18-20 mm. Ray formation and ossification is very prolonged, however.

Transparent dorsal and ventral finfolds are present throughout larval development. The dorsal finfolds are deep (50-53% of H max) and leaf-like in appearance. The anterior portion inserts at myomere 18-20. The posterior portion inserts just posterior to the dorsal fin and ends just above the level of the posteriormost rays of anal fin.The ventral finfold is relatively small, it begins closer to the head, continues along the trailing part of the gut, and ends at its middle part. A short ventral finfold is also present in front of the anal fin.

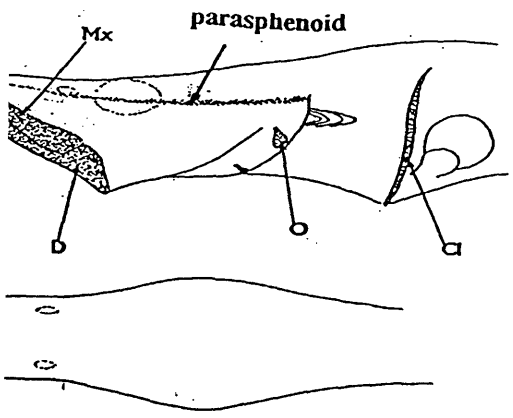
Ossification

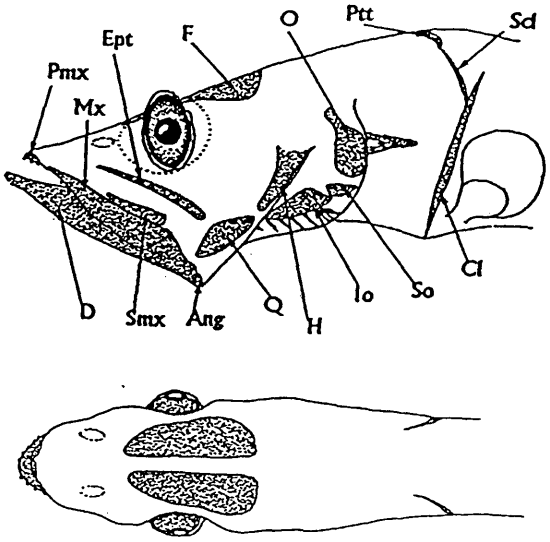
The smallest larva available showed almost complete notochord flexion. Thus, flexion probably begins quite early during the development. However, throughout the larval period, the only structures that show ossification are the unpaired fins, parts of the head, pectoral girdle, and supporting elements of caudal fin.

Head and jaws

In the smallest larvae (18-20 mm SL), the following elements are ossified (Fig. 2 a): parasphenoid, dentary, articular and maxillary bones. Some ossification is visible in the operculum and in the enlarged posterior branchiostegal ray. In larvae 25-32 mm SL the ectopterygoid, quadrate, hyomandibular, interoperculum and subopercular

Fig. 2 . Development of head bones in *Astronesthes sp.* : a) 18 mm, b) 29 mm, c) 47 mm SL. Symbols: Ang - angular; Cl - cleithrum; Ept - ectopterigoid; D - dental; F - frontal; H - hyomandibular; Io - interoperculum; Mpt - metapterygoid; Mx - maxilla; O - operculum; Pmx - premaxilla; Ptt - posttemporal; Q - quadrate; S - supraoccipital; Scl - supracleithrum; Smx - supramaxilla; So - suboperculum; Sy -symplectic. Stippled - ossified regions.


Mx
parasphenoid
D
O
Cl


Ept
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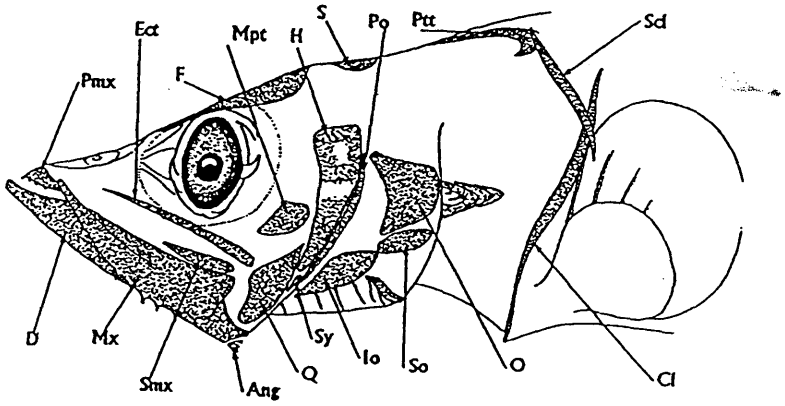
b


Ect
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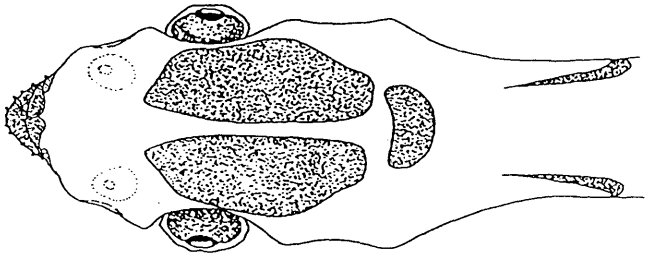


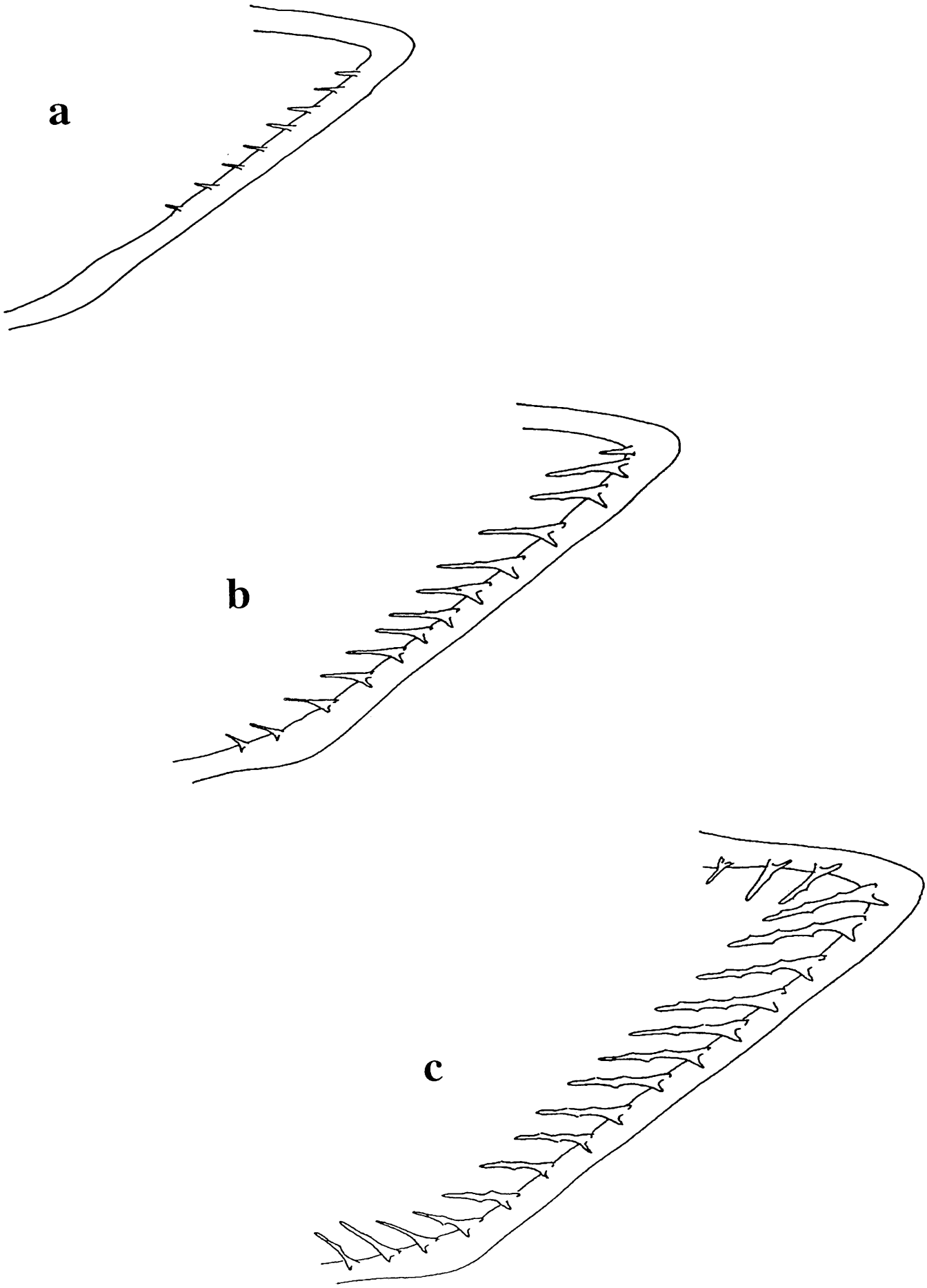
begin to ossify (Fig. 2b). Frontals are well ossified. In upper jaw premaxilla and supramaxilla ossify. The most posterior branchiostegal rays begin to ossify with ossification proceeding anteriorly. A full complement of 20 rays is acquired by 44-45 mm SL. In the largest larvae (40.0 - 47.0 mm SL) supraoccipital, epioticum, preoperculum, metapterygoid and symplectic show well developed ossification (Fig. 2c).

Gill arches

In the smallest larvae (18-20 mm SL) only middle part of ceratohyal is ossified among the bones of hyoid arch. The middle portion of the ceratobranchial is ossified. Most gill rakers on ceratobranchial are formed but not ossified (Fig. 3a). Third and fifth pharyngobranchial toothplates are already formed and ossified. Third plate is smaller than the fifth one and has 1-2 teeth on it.

In larvae 25 -32 mm SL in hyoid arch slightly ossify epihyal, hypohyal and urohyal. In gill arches gill rakers continue to form and ossify and some form on epibranchial and hypobranchial (Fig. 3b), but ceratobranchial remains the only ossified bone. In largest larvae 40.0 - 47.0 mm SL in hyoid arch ossification in epihyal and hypohyal is completed but urohyal is only partially ossified. In first gill arch some ossification is present in epibranchial. By this size a full set of gill rakers is formed and ossified. Gill rakers are long and thin with few short spines in its surface (Fig. 3c). Third and fifth pharyngobranchial toothplates bear 1-2 and 4-5 small teeth respectively.

Fig. 3 Gill rakers development in *Astronesthes sp.* : a) 22.0 mm, b) 30.0 mm, c) 45.0 mm.


a
b
c

Paired fins

In larvae 18-20 mm SL, the ossified cleithrum is long and slender. The supracleithrum and posttemporal bones begin to ossify at 23-24 mm SL. Ossification of pectoral-fin rays begins at size 38-40 mm SL but evidently very prolongated in time. In largest larvae 40-47 mm SL only 4-5 upper pectoral-fin rays are ossified. Formation and ossification of pelvic-fin rays occures quite fast at size 37-40 mm SL.

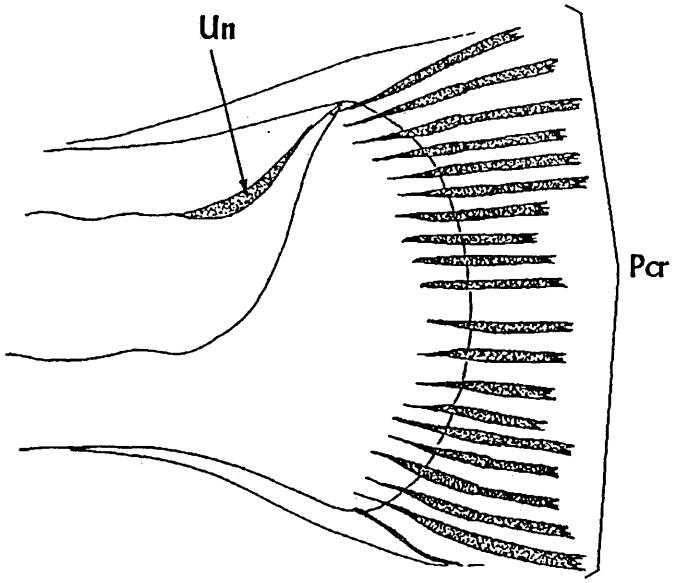
Unpaired fins

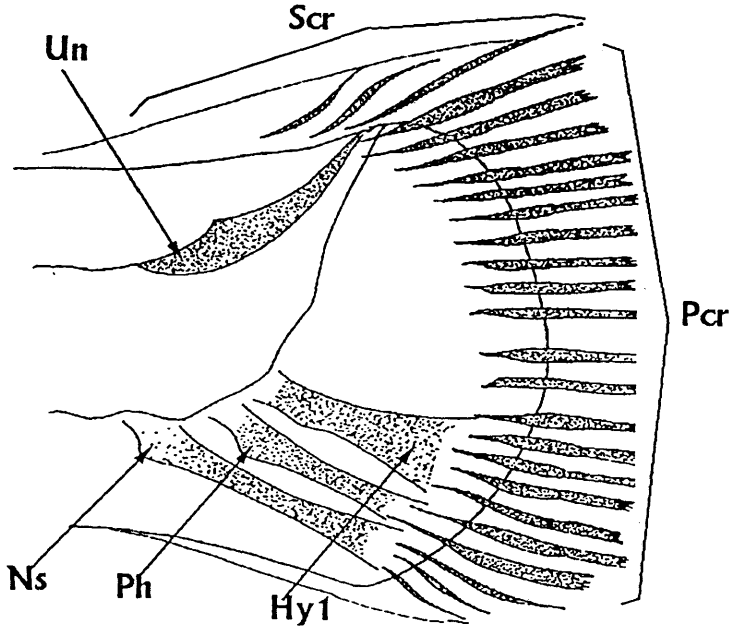
In larvae 18-20 mm SL, the principal caudal rays and uroneural are already well ossified (Fig. 4a). In dorsal and anal fins most of the rays are also ossified. Ossification of the rays in these fins proceeds posteriorly and anteriorly. In larvae 25-32 mm SL ossification spreads on parhypural and hypural 1 and also last haemal spine. Ossification also develops in 2-3 upper secondary caudal rays (Fig. 4b). By 30-32 mm SL the formation of dorsal fin rays is completed but the formation of rays in anal fin is delayed till 35-36 mm SL. In larvae 40-47 mm SL ossification spreads on all hypurals, 1-3 haemal and neural spines of the last vertebrae and 7-8 upper and 4-6 lower secondary caudal fin rays (Fig. 4c).

Axial skeleton

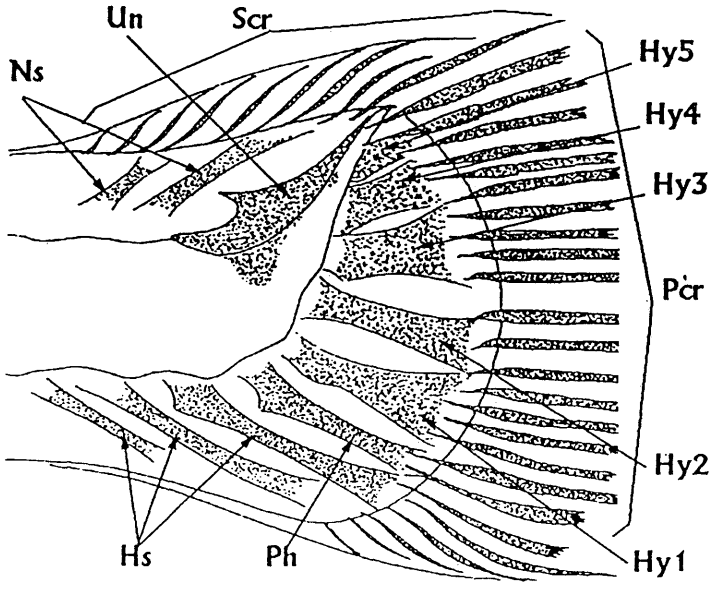
No ossification of vertebrae was observed, exept two saddle-like patches of ossification in the urostyle in largest larvae. The notochord resembles a tube with a thickness of about 0.66 Hmax.

Fig. 4 Development of caudal complex in *Astronesthes sp.* : a) 18 mm, b) 29 mm, c) 47 mm SL. Symbols : Hs - haemal spine; Hy - hypural; Ns - neural spine; Pcr - principal caudal rays; Ph - parhypural; Scr - secondary caudal rays. Stippled - ossified regions





b



c

Dentition

The smallest larvae (18-20 mm SL) have 6-7 minute teeth positioned laterally on the dentary and 11-13 small maxillary teeth. At (23 - 24 mm SL) 3-4 teeth appear on the premaxilla. Subsequently, there is no increase in teeth number during development, and larval teeth are retained on the largest metamorphosing specimen (44 mm SL).

Photophores

Branchiostegal photophores (BR) jn = 20 are the first to form in 40-41 mm SL larvae. Unpigmented buds of PV, VAV, and AC photophores form almost simultaneously at 46-47 mm SL with counts as follows - PV 20-21; VAV 26-27, AC 12-13. In the largest specimens (44.0 mm SL) 8 IP photophores formed. The same specimen posesses three opercular photophores, suborbital and postorbital luminous organs. Thus, all photophore buds of the ventral series, but none in midlateral series, appear before metamorphosis.

Pigmentation

Larvae are very lightly pigmented. The most persistent and invariable melanophores are situated in a row anterior to the pectoral fins and near the ventral body profile. Minute melanophores are scattered along the trailing gut in larvae 18 -30 mm SL, however this pigment was not observed in metamorphosing specimens. Additionally, small larvae (18-25 mm SL) have small melanophores on the dorsal and ventral finfolds, however in larger larvae these pigment cells disappear.

DISCUSSION

Considerable confusion exists in the systematics of astronesthine fishes at the species level, and the current classification is based almost entirely on adult characters. Fink (1984), noted that the group is not monophyletic. *Neonestes* is considered the sister group of all other stomiids, but Fink (1984) noted that there is insufficient evidence regarding the position of the other genera. At present, there is very little information available on the early ontogeny of the astronesthine fishes. Most known larvae are identified only to generic level and published descriptions are not detailed. Numerous aspects of osteological and morphological development, pigmentation and other details of early ontogeny remain undescribed.

The use of vertebral counts, morphometrics and barbel morphology can not be very helpful in ontogenetic studies of astronesthines, since such characters either not formed during early ontogeny or are of limited use due to the great changes in body proportions during metamorphosis. Photophore counts and pattern are taxonomically useful, but their formation occurs late in development. Moser (1996a) described two major morphological types of astronesthine larvae: 1) those with a laterally compressed body and an elongate, sometimes slighly trailing gut, and 2) those with a body rounded in cross section and a trailing gut that is deflected from the body. The morphology of the larvae in present study is similar to the second morphotype.

On the assumption that myomere number corresponds to the number of vertebrae, myomere counts were compared to published data. The number of myomeres (60-62) of larvae was higher than any other astronesthine species, with the

exeption of three high-count species of *Astronesthes* described (Gibbs and McKinney, 1988) and two species of *Borostomias.* Species of *Borostomias* were eliminated since *B. mononema* has photophore counts in the PV (23-25) and VAV (21-25) series that differ from metamorphosing specimens (19-21 and 26-27 respectively) see Table 3, and *B. antarcticus* has 22-26 in the PV and 18-25 photophores in the VAV series. Based on meristic characters (Table 4), the larvae are assigned to one of the "high - count" species of *Astronesthes* from the Southern Subtropical Convergence (Fig. 5b), treated by Gibbs and McKinney (1988). These authors described two new species, *A.spatulifer* and *A.kreffti,* and re-described *Astronesthes* (=*Cryptostomias*) *psychrolutes,* all of them having the highest serial-photophore counts (67-71 IC, 44-47 OA) and vertebrae counts (60-63) in the genus. Numbers of dorsal- and anal- fin rays of larvae are most similar to those counts for *A.spatulifer.* Counts of PV, VAV and AC photophores in larvae overlap those reported for *A.kreffti, A.psychrolutes* and *A.spatulifer* (Table 3). Adult species of astronesthines lack true gill rackers, instead having knob-like gill teeth. Larvae possess well developed gill rakers (Fig. 3), a condition consistent with the description of Gibbs and Weitzman (1965), in which gill rakers degenerate, transforming to knob-like gill teeth during ontogeny. Assuming no loss of gill rakers during ontogeny, numbers of gill rakers in larvae (18-20 gill rakers) are most similar to numbers of gill teeth in *A.spatulifer* (Table 1). However, considering the degree of overlap in other meristic and photophore counts data, certain identification must await the availability of a full transformation series of this species.

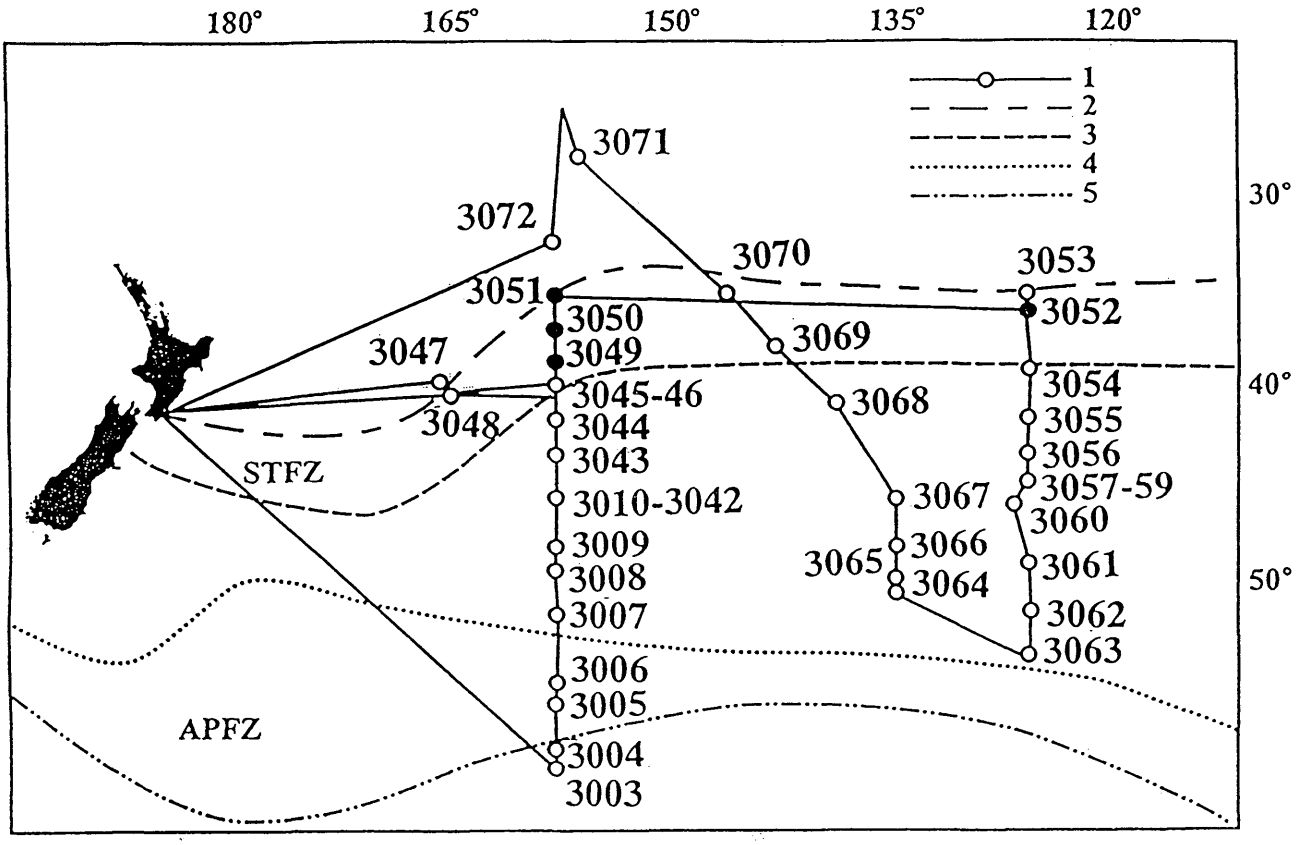
During metamorphosis astronestine larvae undergo significant body shrinkage.

Table 4. Comparison of meristic counts of high-count *Astronesthes* species from the Southern Subtropical Convergence (data from Gibbs and McKinney 1988, and this study)

Species	Dorsal Rays					Anal Rays					Gill teeth									Total vertebrae			
	13	14	15	16	17	15	16	17	18	19	12	13	14	15	16	17	18	19	20	60	61	62	63
A. kreffti			10	1	1			5	6				4	4	4	1					1	5	3
A.psychrolutes		1	9	15	1	2	8	11	2	2	2	2	1	7	9	4	1				2	6	5
A. spatulifer	8	11	2				3	4	12	2						4	4	9	1	2	7	2	
Larvae in present study	2	22	13					1	9	10							5	12	4	7	31	14	1

Fig. 5 a) Distribution of *Astronesthes sp.* larvae collected during 34th cruise of R/V "Dmitrii Mendeleev". ○ - stations ● - stations with *Astronesthes sp.* larvae; b) distribution map of *Astronesthes psychrolutes*, *kreffti* and *spatulifer* (from Gibbs and McKinney, 1988).

a


180°
165°
150°
135°
120°
30°
40°
50°
1
2
3
4
5
3071
3072
3070
3053
3051
3050
3049
3052
3069
3047
3048
3045-46
3068
3054
3044
3055
3043
3056
3010-3042
3067
3057-59
3060
3009
3066
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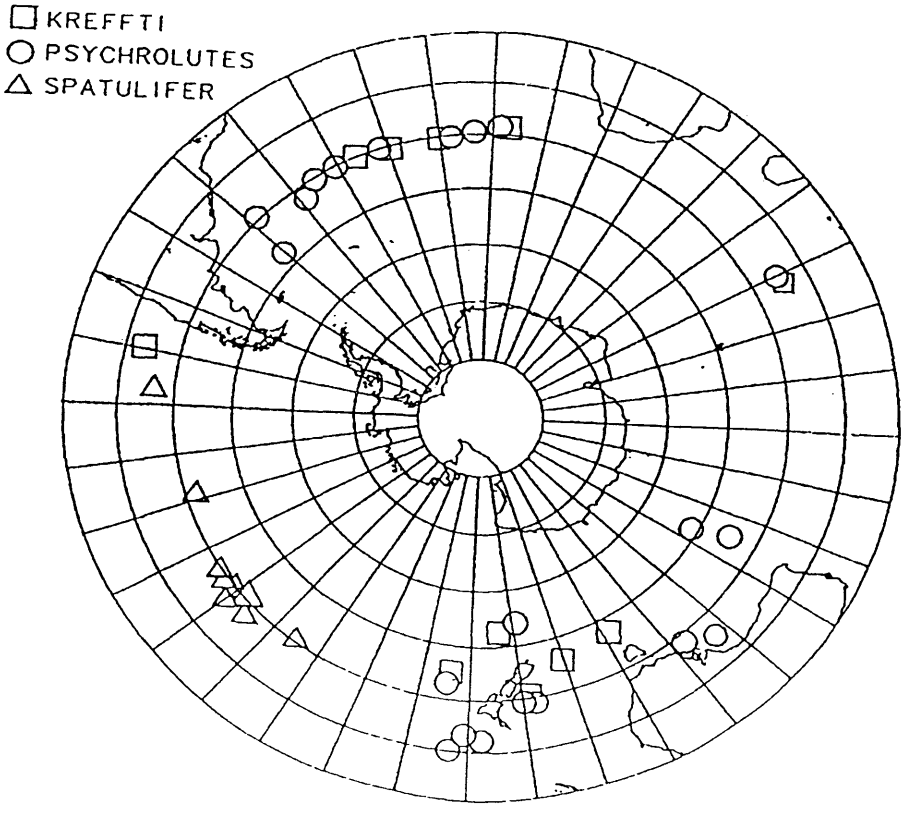
STFZ
APFZ

b


KREFFTI
PSYCHROLUTES
SPATULIFER

Thus, the largest specimens in the series (46-47 mm SL), retained many larval characters (trailing gut, median finfolds, incipient hypaxials) and posessed body photophores. However, one specimen (44.0 mm SL) in the series is more advanced in its development than the larger larvae, having more photophores in later stages of development, well developed hypaxials, a degenerating trailing gut and median finfolds, and more pelvic-fin rays.The gut of this specimen is almost completely integrated within the body walls. Juveniles of astronesthines reported in taxonomic studies may have range 20-30 mm SL (Gibbs and Amaoka, 1984; Parin and Boroduina, 1995), and most juvenile specimens of *Astronesthes spatulifer*, were 36-40 mm (Gibbs and McKinney,1988).

Body shrinkage during metamorphosis is a well known feature of halosaurid and notacanthid leptocephalii in the superorder *Elopomorpha* (Smith, 1970; Smith, 1989), with the most remarkable degree reported for notacanthids (Nielsen and Larsen, 1970; Castle, 1973). Although not as pronounced, a similar ontogenetic pattern is common among stomiatoid fishes. Sanzo (1969) first reported significant body shrinkage for larvae of *Argyropelecus*, *Ichthyococcus*, *Vinciguerria*, *Stomias* and *Chauliodus*. These taxa reach maximum length as late larvae and undergo some shrinkage during metamorphosis followed by regrowth as juveniles. Significant body shrinkage in *Chauliodus*, placed next to the astronestines in phylogenetic scheme of Fink (1984) was also reported by Moser and Kawaguchi (1984). Larvae of *Chauliodus* may reach the impressive length of 49 mm SL before transformation (Moser, 1996b), a size comparable to largest astronesthine larvae in this study. Among gonostomatid

genera, a significant body shrinkage was observed for *Diplophos* species (Ozawa and Oda, 1986; Watson, 1996a). Watson (1996b) reported body shrinkage during metamorthosis for *Argyropelecus* species and also for *Vinciguerria poweria* (Watson, 1996c). Ahlstrom and Counts (1958), described body shrinkage in *Vinciguerria* although not to such extent as was reported by Sanzo (1969). These authors hypothesized that length cannot decrease to any appreciable effect, if the vertebral column is completely formed before metamorphosis. Observations of *Astronesthes sp.* larvae in this study demonstrates that significant body shrinkage does occur during metamorphosis, and suggest that shrinkage is facilitated by the absence of ossification in the vertebrae in metamorphosing specimens. A full series of transforming specimens, would allow detailed descriptions of *Astronesthes* metamorphosis, but was not available in the present material.

DISTRIBUTION

Larvae of *Astronesthes sp.* described in this study occurred in the narrow band of Subtropical Convergence waters (Fig. 5 a). The greatest number and the largest larvae (18.0 - 48.0 mm SL) were caught on the westernmost transect (St. 3049, 3050, 3051). Only three metamorphosing larvae (40-47 mm SL) came from the easternmost transect (St. 3052). Considering the general pattern of circulation in this region the data suggest that spawning of the species occures in the western parts of Subtropical Convergence in the South Pacific. The general distribution of larvae is consistent with that reported for high-count *Astronesthes* described by Gibbs and McKinney (1988)(Fig. 5b). These authors designated *Astronesthes kreffti*, *A.spatulifer*, and *A. psychrolutes* as Subtropical Convergence species based on the distribution of adults.

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CHAPTER 3

Ichthyoplankton assemblages in the south western Pacific

INTRODUCTION

Biogeographical studies of oceanic ecosystems provide important information on how complex biological communities are controlled and organized by physical oceanic processes. Such studies occupy an important role in marine biology. Since the early biological explorations of the world ocean, it has become apparent that most pelagic marine taxa are not homogeneously distributed. Numerous studies (Ebeling, 1962; Johnson and Brinton, 1963; McGowan, 1971, 1974, Barnett, 1983, 1984) confirm that large scale distribution of marine plankton and fish corresponds to major hydrological zones, and provide a basis for identification of distinct biogeographical provinces in the ocean.

A biogeography of the pelagic waters of the Southern Ocean (SO) is not well understood, but the major zoogeographical provinces of the SO are defined generally. The water masses in the Southern Ocean have a distinct latitudinal pattern, with each continuous water mass encircling the Antarctic continent. The oceanic fronts that separate each water mass can serve as effective biogeographical barriers that prevent mixing of constituent different faunas. Based on distribution of pelagic fish in the open waters of the South Pacific Andriashev (1965) distinguished three major biogeographical divisions: the Antarctic Zone ("Zone of *Electrona antarctica*"), the Notal (Subantarctic) Zone ("Zone of *Electrona subaspera*") and the Subtropical Zone ("Zone of *Scomberesox saurus*") - to the north of the Subtropical Convergence. McGinnis (1974), analyzing the distribution of myctophids south of 30° S, identified the Antarctic-Antarctic Polar Front, Subantarctic, Transitional and Warm-Water lanternfish complexes, each associated with major

hydrographic phenomena. More recent studies continue to add more faunal and spatial details and refine the large picture (Barchatov, 1985; Dolzhenkov, 1982; Pachomov, 1993)

Almost all pelagic fishes, including the most diverse and abundant mesopelagic ichthyofauna and fishes from greater depths, have planktonic eggs and larvae that develop in productive surface waters. As a result, the epipelagic zone contains a unique assemblage of early life history stages of fishes, collectively known as ichthyoplankton. In general, young stages of fishes are more easily captured than adults, and ichthyoplankton studies have proven to be important for the fields of fisheries, oceanography and systematics.

Investigations of larval fish assemblages have increased over the past several decades, showing an increasing interest in ichthyoplankton ecology and dynamics. A massive amount of data accumulated on ichthyoplankton composition and abundance from major ocean regions, e.g. Western Atlantic - Richards (1984), Richards et al (1989); Eastern Atlantic - Olivar (1990), Sabates (1990); Eastern Pacific - Ahlstrom (1972), Leis and Miller (1976), Loeb (1980), Western Pacific - Leis and Goldman (1987), Young et al (1986); Antarctic - Kellerman and Schadwinkel (1991), Efremenko (1979). Some studies apply data on ichthyoplankton distributions in identifying biogeographical regions in particulate areas (Loeb and Nichols, 1984; Loeb, 1986).

A recent approach to investigating ichthyoplankton spatial patterns has been to define larval fish assemblages and relate their occurrence and variability to the biology of the adult fishes and to the pelagic ecosystem in which they exist. Numerous studies (Richardson and Pearcy, 1977; Richardson et al., 1980; Loeb et al., 1983; Moser et al.,

1987; Sabates, 1990) have identified larval fish assemblages that correspond to distinct oceanic zones as well as reflect the habitat and spawning behavior of the adult fish.

Ichthyoplankton of subantarctic waters of the Pacific Ocean is poorly known. Limited data on certain fish larvae and juveniles are available from works of Regan (1916) and Johnson (1982). A few ichthyoplankton surveys were carried in the coastal waters of New Zealand (Robertson, 1973) and in the limits of a 200-mile zone (Robertson and Mito, 1979), but no information was available on ichthyoplankton of south-western Pacific before the work of Evseenko (1988), outlining preliminary results of ichthyoplankton survey carried out during the 34th cruise of R/V "Dmitrii Mendeleev".

The primary goal of the 34th cruise of Russian RV "Dmitrii Mendeleev" was to study poorly known pelagic ecosystems of the vast Subantarctic region in the Pacific. This broad region has remained the least studied portion of the Pacific Ocean. Its pelagic ecosystems are generally judged by analogy with observations made in the subantarctic waters of other oceans and in the waters east of New Zealand. During the expedition, biological studies were conducted on a range of different organisms from bacterioplankton to fish in order to understand the structure and behavior of pelagic communities, potential productivity of this area, and the principles governing distribution of species on different scales of space and time.

The present study is based upon extensive ichthyoplankton data collected during this cruise. The aims of this chapter are: to apply techniques of numerical ecology to detect, describe and interpret the major distributional patterns of ichthyoplankton assemblages; to search for environmental variables significantly responsible for changes in

species composition along the environmental gradients; to search for relationships between the spatial heterogeneity of ichthyoplankton community and the varying water masses in the area; to examine the correspondence of ichthyoplankton assemblages to existing concepts of zoogeographical zones in the region; and to search for correlations between zoogeographical divisions as inferred from distribution of adult fish and their early life history stages.

MATERIALS AND METHODS

Collections

Ichthyoplankton samples and environmental data for this study were collected aboard R/V "Dmitrii Mendeleev"during January -March 1986. The cruise was organized by the Institute of Oceanology (USSR Academy of Sciences) with the task of studying the pelagic ecosystems of the central and western sub-antarctic zones of the Pacific. The ichthyoplankton collections came from 24 stations along three North-South transects on I) 57°16′, 157°40′W to 27°13′S, 156°54′W; II) 52°03′S, 125°14′W to 37°56′S, 125°55′W; III) 48°32′S, 134°58′W to 37°43′S, 143°00′W (Fig. 1). Most of the samples were collected by a 3.3m Isaaks-Kidd midwater trawl with a Samishev-Aseev modification (bag - 25 m, mesh size - 5 mm, caprone sieve No. 15 in the codend). This modification of the trawl increases catches and reduces capture damage (Bekker and Evseenko, 1987). Most deployments of the trawl were made between 0-200 m at night as stepped oblique hauls. Each step of the gear covered about 30 m depth, and the duration of each step was 5 min at stations 3003-3008, or 2 min at all other stations. Thirty eight samples, collected with Isaaks-Kidd trawl were chosen for analysis. Sample numbers and corresponding stations are shown in Table 1. The total water volume filtered was estimated as 49,000 m^3 at stations 3003-3008 and 37,000 m^3 at all other stations. Samples were fixed in 4% buffered formalin seawater solution immediately after each haul. In subsequent laboratory analysis, all fish larvae were identified to the lowest possible level.Identification of larvae was facilitated by reference to various guides such as (Moser and Ahlstrom, 1984, Efremenko, 1979) as well as some references on adult fishes (Smith and Haemstra, 1986).

Fig. 1 Cruise track and stations locations from 34th cruise of R/V "Dmitrii Mendeleev" with 38 samples used in a present study. 1) cruise track and stations locations; 2) southern tropical convergence; 3) front of the southern boundary of the STFZ; 4) subantarctic front; 5) antarctic front; STFZ - subtropical frontal zone; APFZ - antarctic polar front zone (from Vinogradov and Flint, 1986).

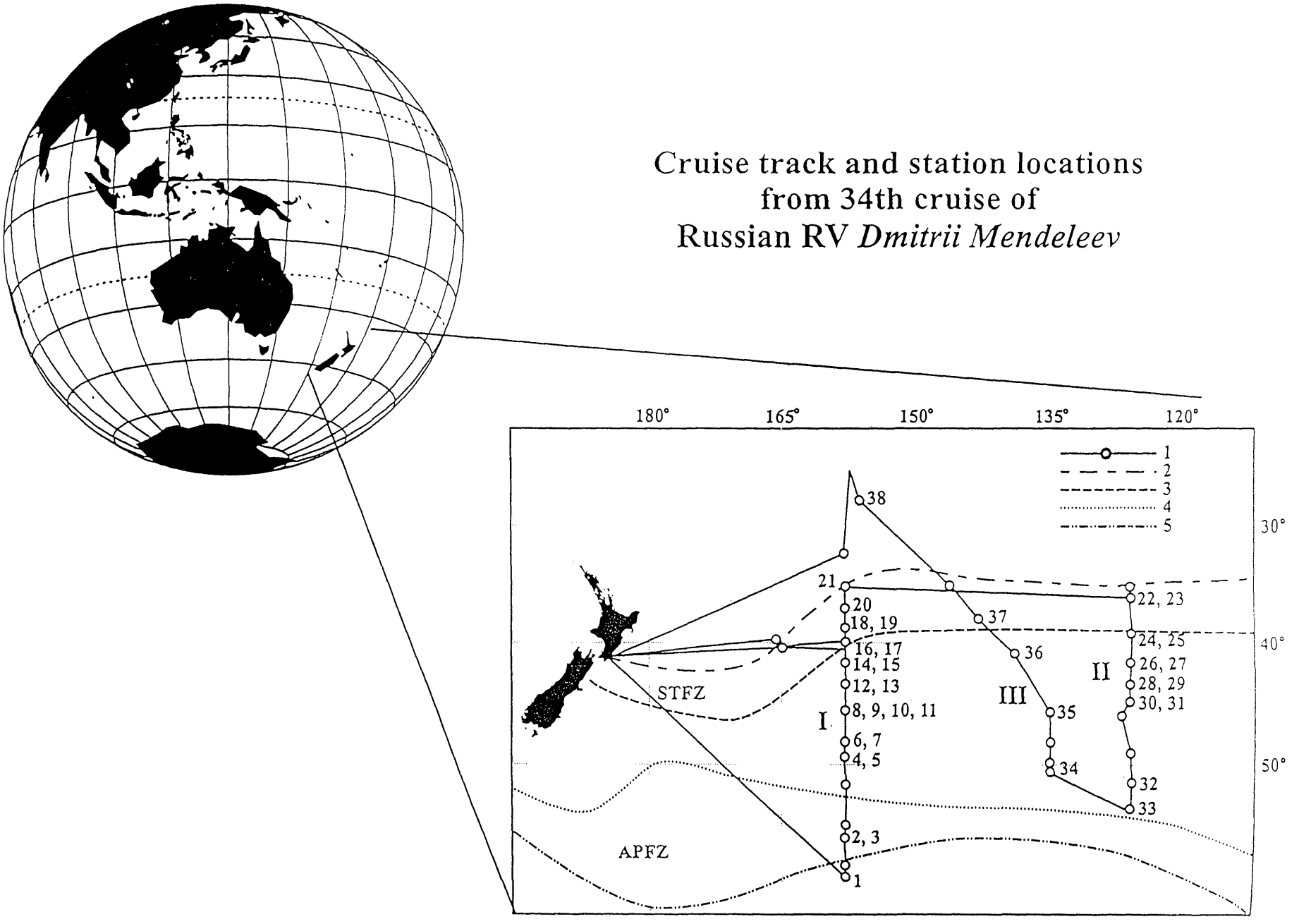

Cruise track and station locations
from 34th cruise of
Russian RV *Dmitrii Mendeleev*
180°
165°
150°
135°
120°
30°
40°
50°
1
2
3
4
5
38
21
20
18, 19
16, 17
14, 15
12, 13
8, 9, 10, 11
6, 7
4, 5
2, 3
1
37
36
35
34
22, 23
24, 25
26, 27
28, 29
30, 31
32
33
I
II
III
STFZ
APFZ

Table 1. Stations numbers in 34th cruise of R/V "Dmitrii Mendeleev" and samples collected with Isaaks-Kidd midwater trawl, used in present study.

Station	Sample	Station	Sample
3003 3(2)	1	3050 111(22)	20
3005 23(4)	2	3051 112(23)	21
3005 24(5)	3	3052 114(25)	22
3008 35(6)	4	3052 115(26)	23
3008 36(7)	5	3054 119(27)	24
3009 38(8)	6	3054 120(28)	25
3009 39(9)	7	3055 124(29)	26
3010 41(10)	8	3055 125(30)	27
3010 41(11)	9	3056 129(31)	28
3042 82(12)	10	3056 130(32)	29
3042 83(13)	11	3057 132(33)	30
3043 87(14)	12	3057 133(33)	31
3043 88(15)	13	3062 134(34)	32
3044 92(16)	14	3063 142(35)	33
3044 93(17)	15	3065 145(36)	34
3045 96(18)	16	3067 147(37)	35
3045 97(19)	17	3068 149(38)	36
3049 107(20)	18	3069 150(39)	37
3049 108(21)	19	3071 152(40)	38

However, there are no guides to the ichthyoplankton of the western-south Pacific. As a result, some myctophids (e.g. *Lampanyctus*, *Gymnoscopelus*, *Protomyctophum*, *Symbolophorus*) could not be identified to species level. In these cases, morphological types that were presumed to be myctophid species (separated on the basis of distinct pigment patterns) were recorded as species 1, species 2 etc.

Data analysis

The analysis of general patterns in zoogeography involves considering many species and many sites on a broad scale, and hence, inevitably requires the use of multivariate methods. Two basic widely used conceptual models for analyzing biological communities are classification and ordination. Classification is a model in which sites, species or variables are arranged into groups. Ordination is oriented toward determining species responses to environmental variables, thus sites and/or species are arranged along environmental gradients.

Among ecologists analyzing species communities, various combination of ordination and cluster techniques are very popular tools and more and more researchers now apply these numerical approaches in ecological works on various marine taxa. A number of recent studies, based on such methods, became available for the different regions of the world ocean (Pinca and Dallot, 1995; Falcon et al., 1996) and for the pelagic waters of the Southern Ocean in particular, analyzing various pelagic organisms ranging from microbial assemblages (Hanson and Lowery, 1985) to macroplankton (Piatkowski, 1989). A few recent studies have successfully used this technique in analyzing ichthyoplankton (Koubbi, 1993; Koubbi et al 1991) and mesopelagic fish

assemblages (Koubbi, 1993).

In my study I chose to interpret data by both classification and ordination with indirect (Detrended Correspondence Analysis, DCA) and direct (Canonical Correspondence Analysis, CCA) methods.

Cluster analysis, as method for classification, is an explicit and well established way of identifying groups in raw data. However, it has been reported, that if there is a continuous structure in the data, cluster analysis can force graded series into discrete clusters (Field et al., 1982). Thus, it is usually appropriate, to compare the results of clustering with some type of ordination (Field et al., 1982; Gauch, 1982). Ordination techniques are all based on weighted-averaging methods that produce a low-dimensional ordination space, in which similar species and samples are close together and dissimilar entities are apart (Hill, 1973, 1974). The method is designed to recover major patterns as the first few "significant" ordination axes, and to relegate individual responses and "noise" within the data to axes formed later (Gauch, 1982). The combination of clustering and ordination can provide an objective, community-centered ordination, especially with heterogeneous or difficult data set, allowing a more meaningful and manageable community analysis (Gauch, 1982).

Classification

Samples and species were classified using Two-Way Indicator Species Analysis (TWINSPAN) (Hill, 1979) on a matrix of ichthyoplankton densities reported as numbers in 1000 m^3 and arranged by species vs. samples (Appendix 1). TWINSPAN is a divisive, polythetic, hierarchical classification method that is most useful when the objective is to

detect the overall patterns of differences in biological data. TWINSPAN uses ordination by CA before imposing each division, and is able to detect numerous gradients if the data structure is multi-dimensional. The result of this classification is a hierarchy of division levels, where important divisions are expected to occur high in the hierarchy, while minor divisions are likely to be found near the bottom. The TWINSPAN program not only classifies the data, but also constructs an ordered two-way table from a site-by-species matrix. Six so-called "pseudospecies cut levels" were used to transform the abundance data. These abundance levels were : 0-0.03, 0.03-0.06, 0.06-0.1, 0.1-0.15, 0.15-1.5, 1.5- 5 specimens/1000 m^3. A detailed explanation of this method is given by van Tongeren (1987).

Detrended Correspondence analysis (DCA)

DCA is a modification of Correspondence analysis (CA) that eliminates nonlinear relationships between axes and distortions of the relative distances between samples (or species) on the ordination axes (Hill and Gauch, 1980). In addition, DCA provides meaningful scaling along axes by plotting ordination scores along a gradient of standard deviation (SD)(Hill and Gauch, 1980), making it easy to visualize the degree of similarities between different samples. Thus, samples separated by more than four SD units can be interpreted as having no species in common.

It was reported (ter Braak, 1988), that Canonical Correspondence Analysis (CCA) is inappropriate for extremely short gradients, in which species abundance or frequency is a linear or monotonic function of gradients. Thus, I used DCA to determine the lengths of the gradients (axes). Gradients that are very long (>7 s.d.) justify the use of CCA, which

assumes species have unimodal response to the environmental gradients (ter Braak, 1995).

Canonical Correspondence analysis (CCA)

CCA is currently considered the most advanced and robust method of gradient analysis (Palmer 1993). It is an extension of correspondence analysis (CA) and a direct ordination method used to relate sample composition to environmental variables. This form of direct gradient analysis has the advantage that it allows the integrated analysis of environmental and biological data, ordination axes for biological data are constrained to be linear combinations of environmental variables. Canonical coefficients and interset correlations are used for interpreting the ordination axes. The canonical coefficients are the coefficients of a weighted multiple regression of the sample scores on the standardized environmental variables. The interset correlations are the correlation coefficients between the environmental variables and ordination axes. The underlying theory for both CCA and DCA is presented in ter Braak (1988).

CCA was used to answer two basic questions - a) to identify distinct species assemblages b) to identify specific environmental variables which account for most of the variation in ichthyoplankton composition.

Fifteen environmental variables - temperature (°C), salinity (ppt) and dissolved oxygen (mg/l) at 0, 50, 100, 150, 200 m depth levels respectively along with geographical components (latitude and longitude) were considered and included in the analysis to define influence of abiotic and geographic parameters on distribution of larval assemblages.

In order to test the significance of the relationships between selected external variables and species data, as well as the significance of the ordination axes, I used a

Monte-Carlo permutation test (ter Braak, 1988).

In addition to classification and ordination procedures, species richness (total number of taxa in sample), Shannon-Wiener diversity (H'), and Pielou index of evenness were calculated for each sample. Species diversity (H') was calculated using formula

$$\sum_{i=1}^{S} (N_i/N)\log_2(N_i/N)$$

where S= total number of species; N= total number of individuals, and N_i = number of individuals in the *i*th sample

Species evenness (J') was calculated using the formula:

$$J' = H'/H_{max}$$

and is the actual diversity of the sample as a percent of the maximum diversity.

RESULTS

Hydrology

The cruise track crossed the contact zone of the subtropical ecosystems of the anticyclonic gyre encompassing the entire southern tropical Pacific and the subantarctic ecosystems of the cyclonic gyre of the antarctic circumpolar current of the subantarctic. Belkin et al. (1988) presented a comprehensive description of the water masses encountered during the cruise. Only a brief account of the hydrological features relevant to the ichthyoplankton distribution will be given here. The general distribution of water masses and hydrological fronts is shown in Fig 1. Plots of hydrological data from separate stations are given in Fig 2.

Antarctic Zone

The antarctic zone was represented only by station 3003. Thermal structure of Antarctic zone is characterized by mixed and warm upper layer, below which temperature is gradually decreasing with depth (Fig. 2a and see Belkin et al. 1988).

Antarctic Polar Front Zone (APFZ)

APFZ was represented by station 3005 on the westernmost transect by 158° W (Fig. 2b). The APFZ is marked by a drop in temperature from north to south of about 3° to 4°C and by a velocity of 15 to 20 cm s^{-1} (Belkin et al. 1988)

Subantarctic Zone

The subantarctic zone is a broad band of water situated between Subtropical Front

Fig. 2 T-S diagrams from different water masses. a - Antarctic zone; b - Antarctic Polar Front Zone; c - Subantarctic Zone; d - Subtropical Convergence Zone; e - Subtropical Zone; f - summary plot for all stations.

Fig. 2a

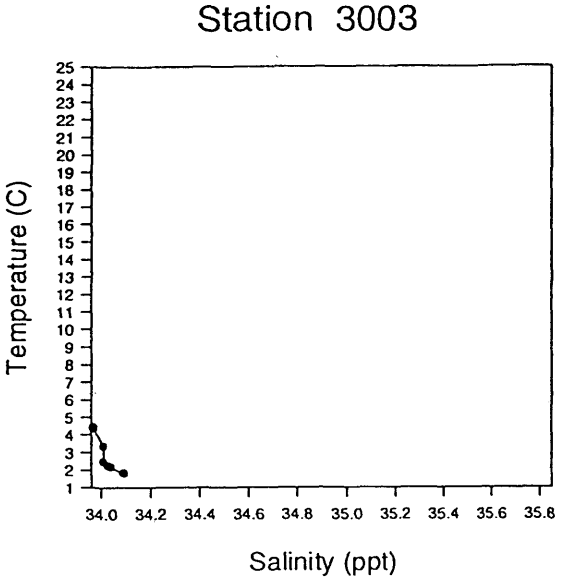

Station 3003
Temperature (C)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
34.0
34.2
34.4
34.6
34.8
35.0
35.2
35.4
35.6
35.8
Salinity (ppt)

Fig. 2b

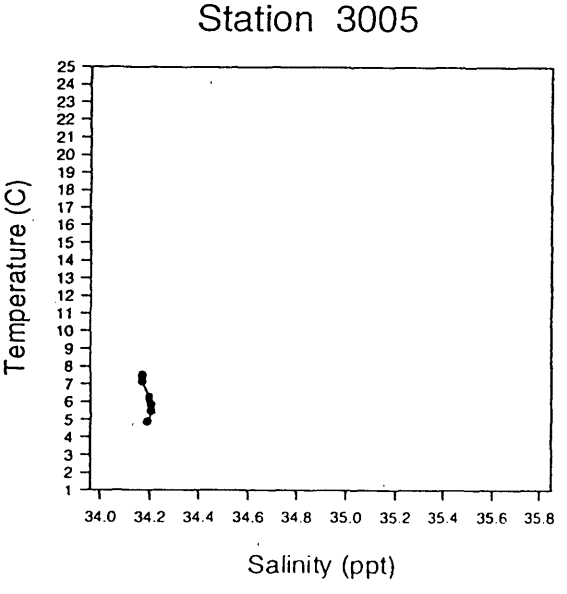
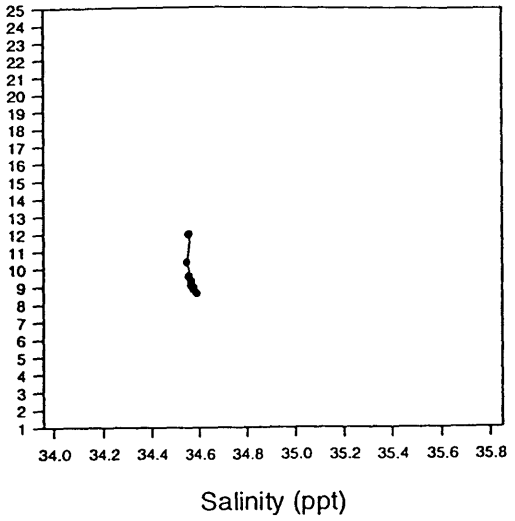
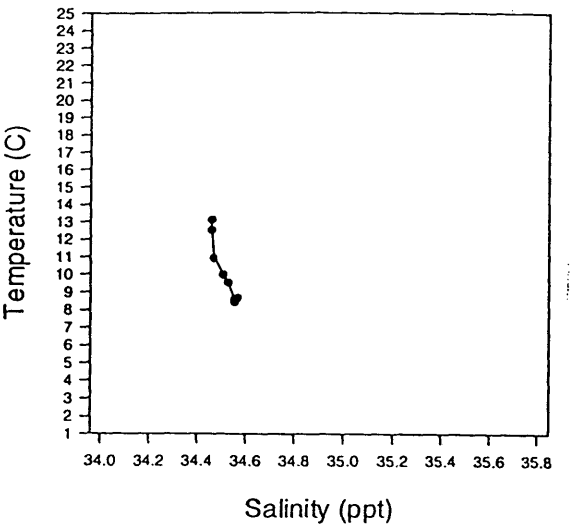

Station 3005
Temperature (C)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
34.0
34.2
34.4
34.6
34.8
35.0
35.2
35.4
35.6
35.8
Salinity (ppt)

Fig. 2c

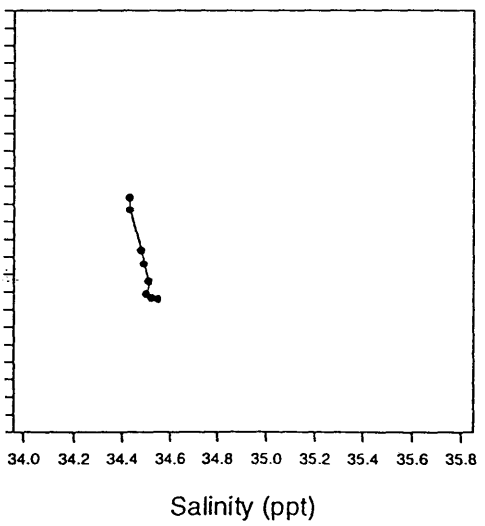
Station 3008



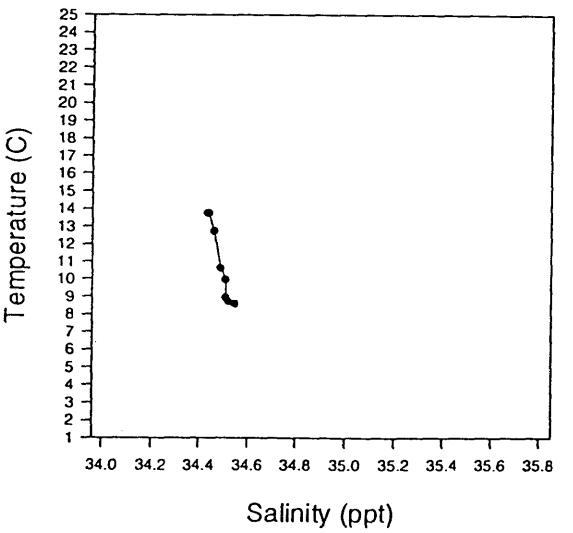
Station 3009



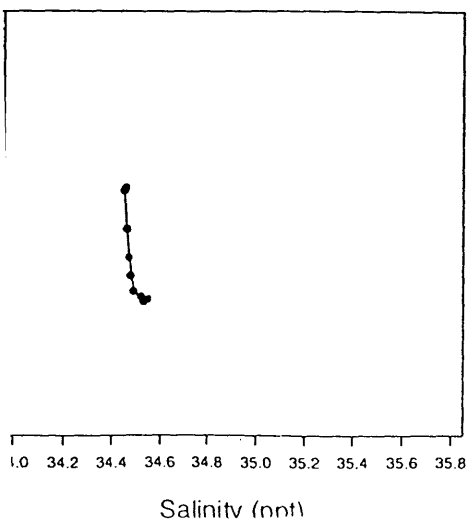
Station 3010



Station 3042



Station 3043



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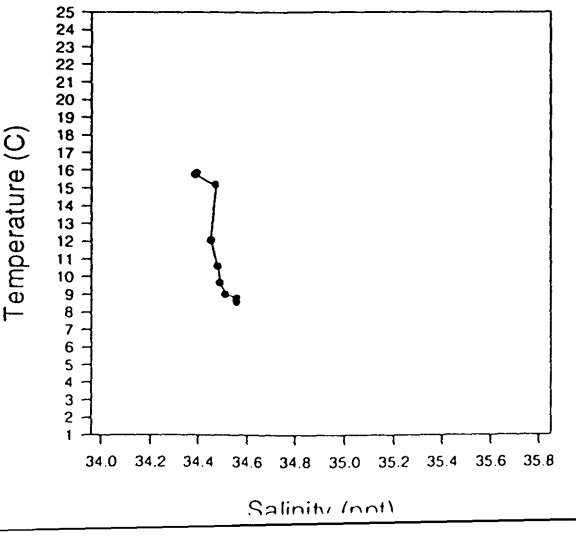
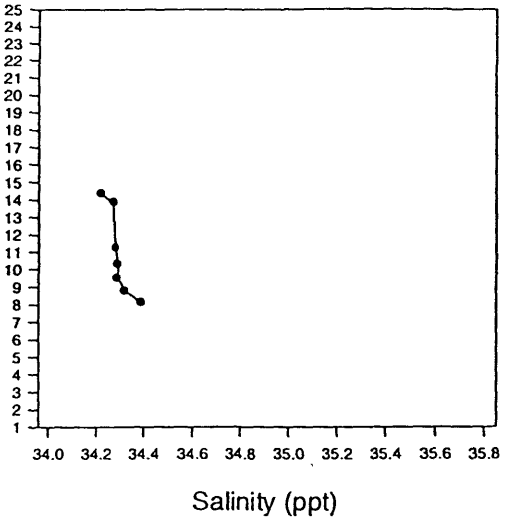
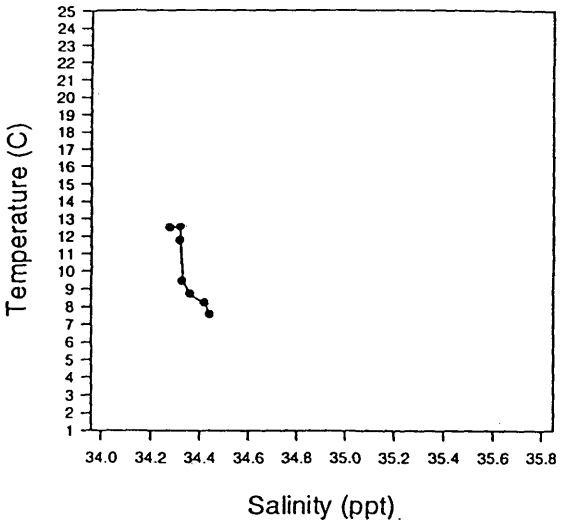


Fig. 2c cont.

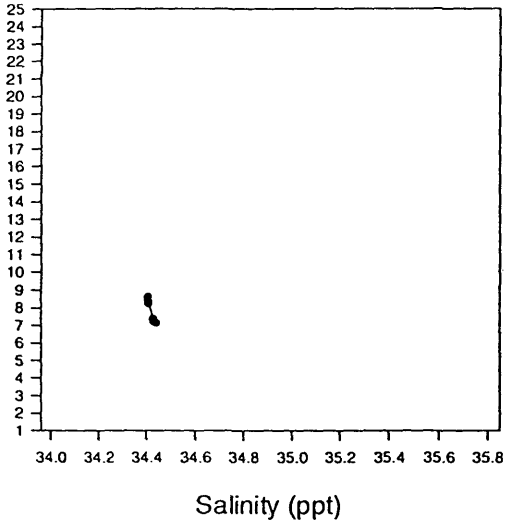
Station 3055



Station 3056



Station 3062



Station 3063

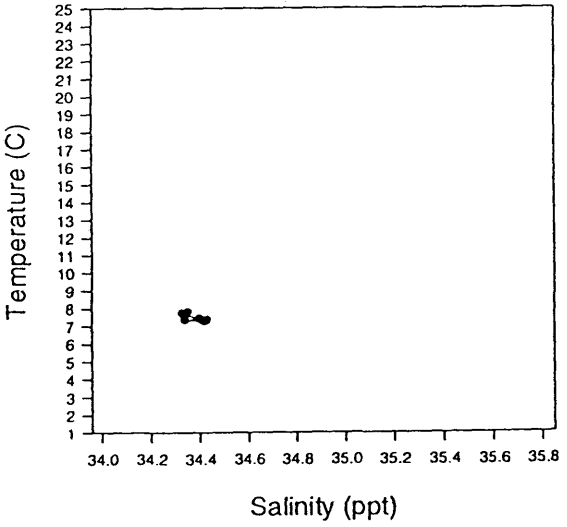
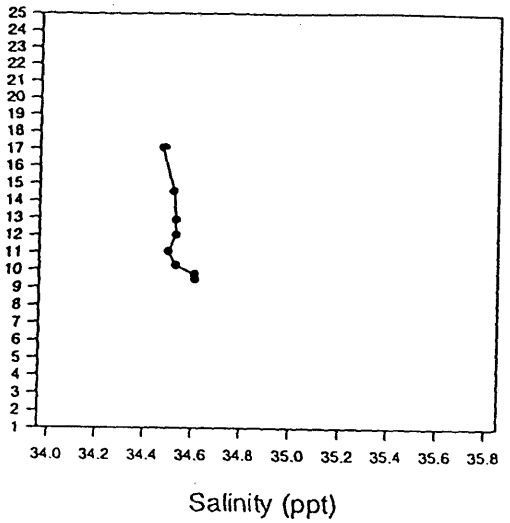


Fig. 2d

Station 3045



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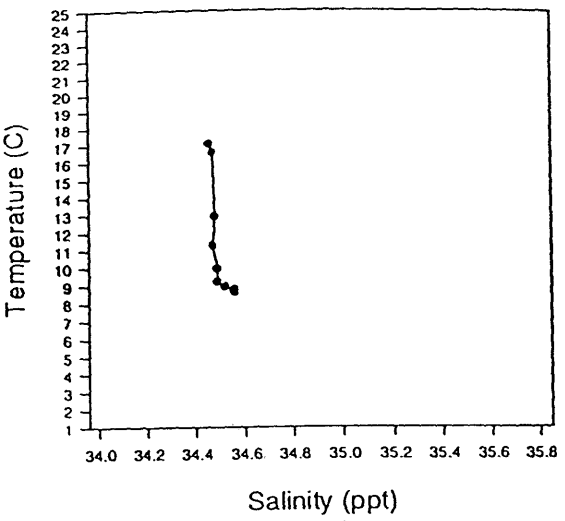
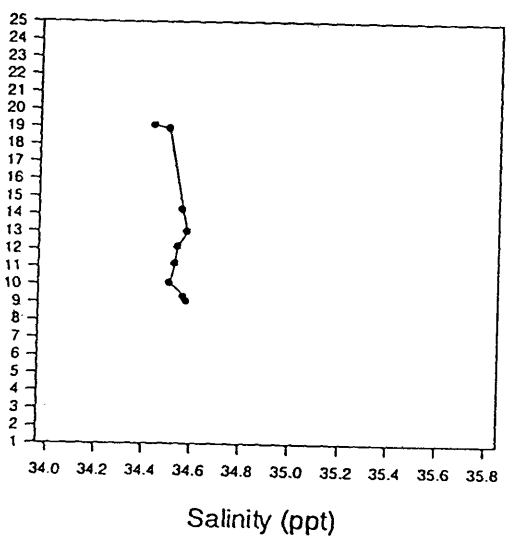
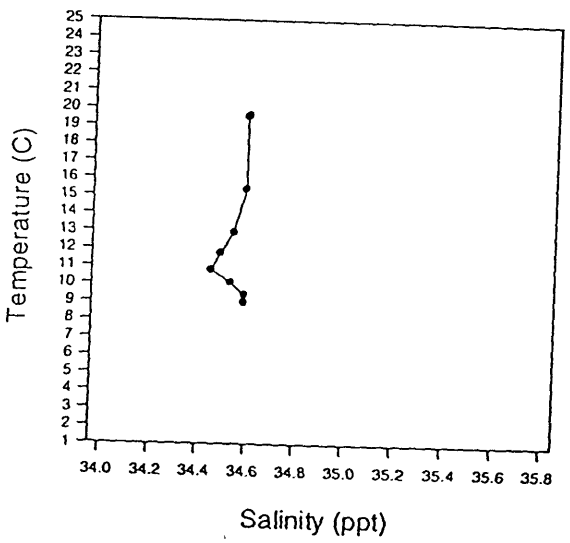


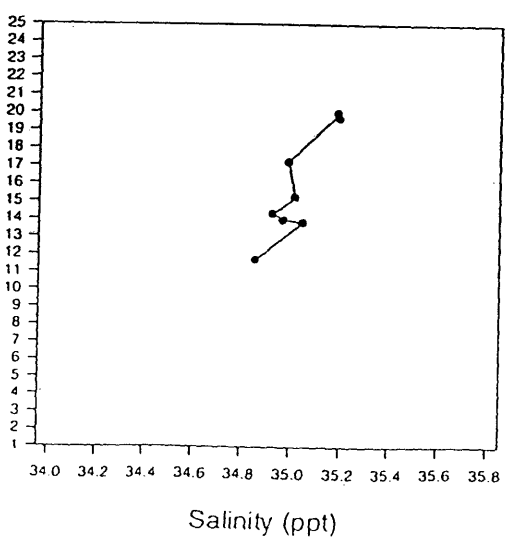
Station 3049



Station 3050



Station 3051



Station 3052

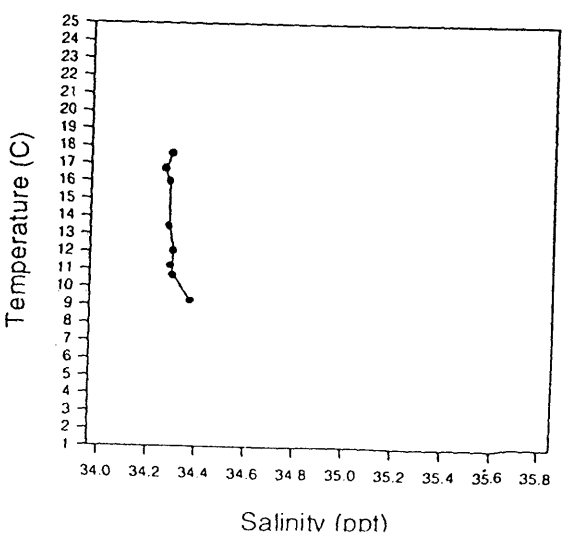


Fig. 2d cont.

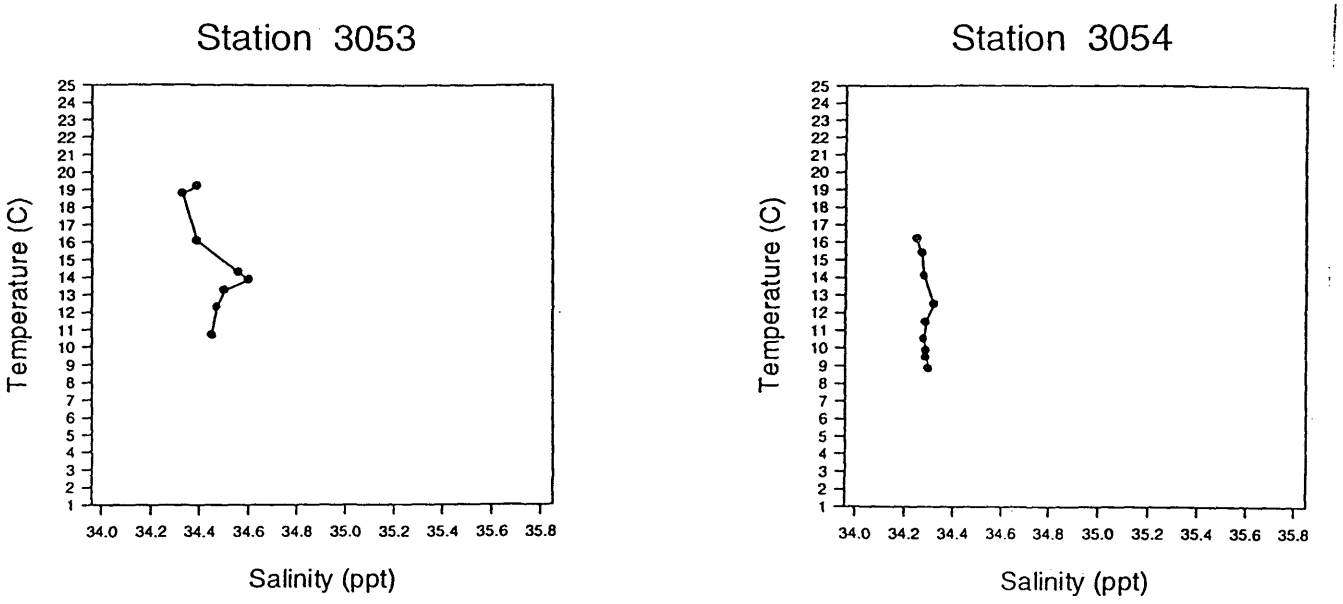


Fig. 2e

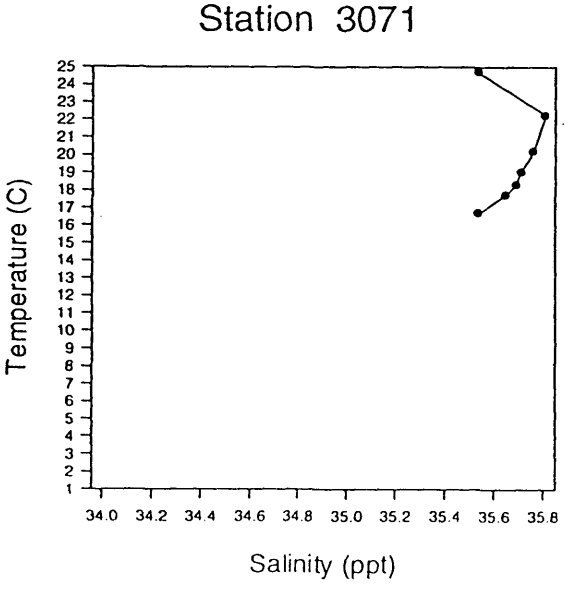
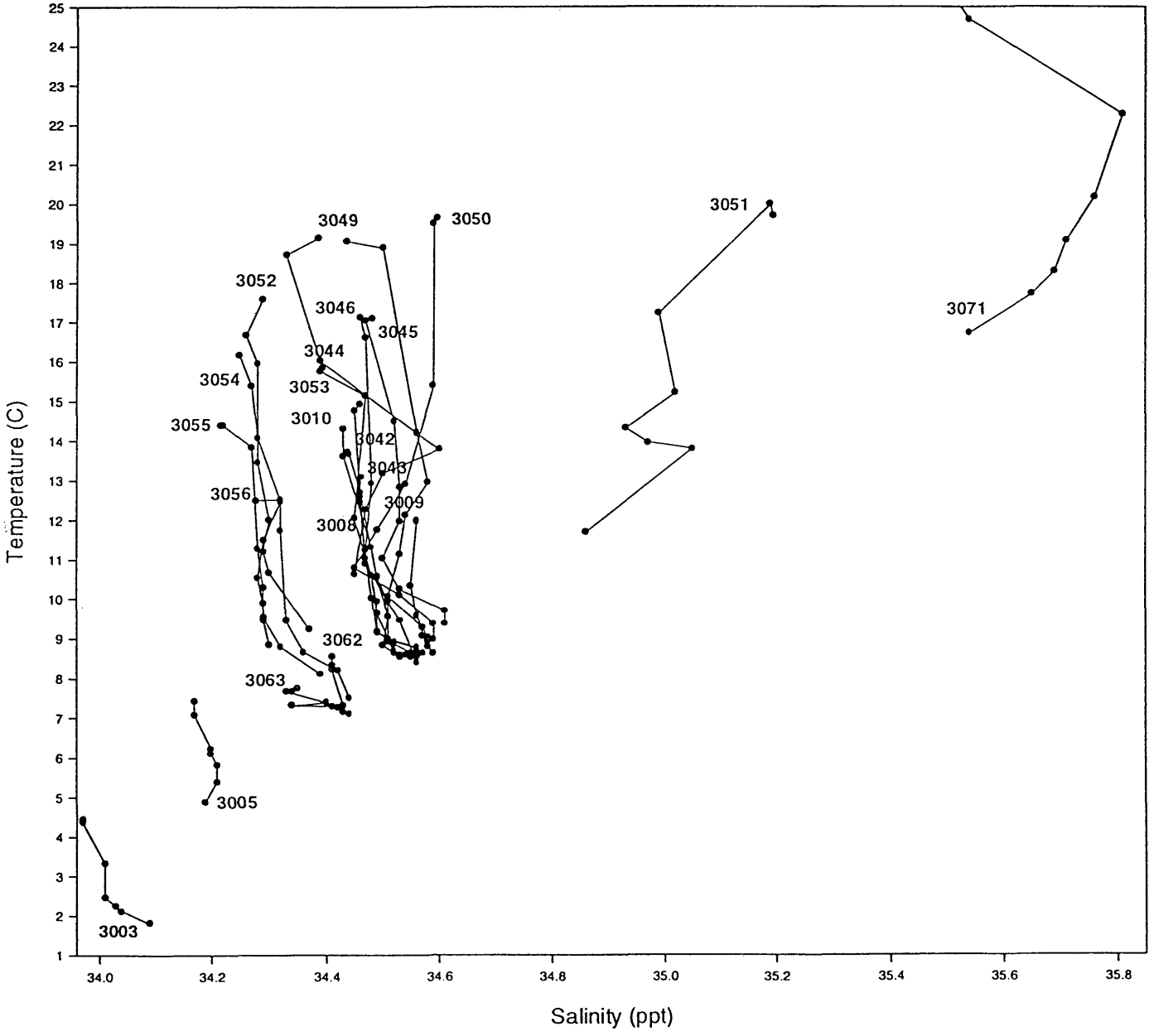


Fig. 2f


Temperature (C)
Salinity (ppt)
3003
3005
3062
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and Subantarctic Front. It is characterized by well mixed waters attributable to mixing processes associated with the sinking Antarctic Water (Deacon, 1933). Subantarctic Zone is closely associated with so called Subantarctic Mode Water (SAMW) - a thick circumglobal sub-surface layer of nearly isothermal water (a thermostad) lying immediately north of the Subantarctic Front (McCartney, 1977, 1982). The horizontal structure of subantarctic zone, quite uniform toward the west (160°W), becomes quite complex to the east (120°W) on the approach to the East Pacific Rise.

Most stations (3008, 3009, 3010, 3042, 3043, 3044, 3055, 3056, 3057, 3062, 3063, 3067, 3068)(Fig. 2c) were situated in the Subantarctic Zone, which allowed its more detailed analysis. It was reported (Belkin et al., 1988) that thermostad is more intense, colder and deeper on the transect on 126° W than on the westernmost one performed on 158° W. Based on these differences, same authors suggested that Subantarctic Mode Water is forming with greater intensity on the easternmost transect. Changes in thermal characteristics in the upper ocean layer are shown by rapid increase in surface temperature from 9° to 11°C between station 3006 and 3007 and rather gradual temperature increase from 11°C on 51°S to 16°C on 41°S. The increase in surface temperature on the transect by 126° is much less gradual and associated with numerous surface thermal fronts (Belkin et al., 1988).

Subtropical Convergence

Stations 3045, 3049, 3050, 3051, 3052, 3054 and 3069 were situated within Subtropical Convergence waters (Fig 2d). The Subtropical Convergence, described by

Deacon (1933, 1937), is a relatively narrow band of water, where enhanced meridional temperature and salinity gradients exist in the upper level waters. This hydrological structure, frequently referred to as Subtropical Front (STF), marks the transition between warm and saline subtropical waters to the north and cool and fresh subantarctic waters to the south. The STF is nearly continuous in the Southern Hemisphere. The hydrological investigations during 34th cruise of "Dmitrii Mendeleev" showed, that Subtropical Convergence is represented by broad (400-500 km) subtropical frontal zone - in the region examined extends along 35-36°S and its southern boundary is at about 40°S, with distinct TS fronts on its northern and southern borders. These fronts, identified as Northern and Southern Subtropical Fronts, were situated between 35-36° and 39-41° respectively (Belkin, 1988). Such hydrological structure is quite similar to that of Antarctic Polar Front Zone, since in both cases there is a broad, monotonous frontal zone with abrupt TS fronts on its periphery. A comparison of STF between subantarctic and subtropical waters shows that its waters can be traced down by no more that 450 m.

Subtropical Zone

The Subtropical Zone was represented by only one station 3071, taken on the periphery of the South Pacific Subtropical Gyre (Fig. 1, 2e).The South Pacific Subtropical Gyre is large, monotonous, and delineated by anticyclonic boundary currents with somewhat ill-defined inner edges. The anticyclonic circulation in this gyre forces sinking of interior waters, a feature that produces a vast oligotrophic central region. Waters of anticyclonic subtropical gyres are characterized by great uniformity of physical, chemical

and biological variables compared to such regions as the California Current or Eastern Tropical Pacific (Reid, 1962; Venrick et al. 1973).

General community structure

A summary of the descriptive statistics for ichthyoplankton data is presented in Table 2. A total of 5695 fish larvae, representing 28 families, 59 genera and 84 species were identified. Myctophidae constituted the dominant family (49.3 %) with the greatest diversity. Other families represented include Scomberesocidae (25.3%), Gonostomatidae (6.7%), Exocoetidae (5.2%), Gempylidae (2.9%), Photichthyidae (2.2%), Stomiatidae (1.9%), Paralepididae (1.6%), Scopelarchidae (1.3%), Sternoptichidae (1.1%). The other families were represented by few individuals. Species diversity was calculated per sample using Shannon-Wiener function (H′) and evenness (J′) index (Pielou, 1975). Those data are summarized in Table 3. The number of species, taken in particular samples varied from 3 in the waters of antarctic polar front to 22 in the STC waters. The average Shannon-Wiener diversity (H′) ranged from 0.89 to 3.18 in southern part of the subantarctic.

Classification

The results of TWINSPAN are summarized in Table 4. The first, major TWINSPAN division (Fig. 3) separates three samples taken at stations 3003 and 3005 and thus represent the sharpest discontinuity. Sample 1 was situated in Antarctic waters and samples 2,3 were taken in the waters of Antarctic Polar Front. This group included four species - *Bathylagus antarcticus*, *Notolepis coatsi*, *Electrona antarctica* and *Krefftichthys*

. Ranked abundance of species in collections of the 34th cruise of R/V "Dmitrii Mendeleev" (mean 1 - number of individuals per sample; mean 2 - number of individuals per number of samples in which species occurred; max - maximum number of individuals per sample; total - total number of species in the collection). Species code number correspond to those used in ordination and cluster analysis.

Species	mean1	SD	max.	total	mean2
Scomberesox saurus	52.473	142.514	700	1994	181.272
Protomyctophum bolini	13.789	28.21	124	524	27.578
Cyclotone spp.	13.526	62.53	388	514	21.416
Exocoetus obtusirostris	10	61.644	380	380	380
Gymnoscopelus sp.1	9.236	13.459	42	351	19.5
Krefftichthys anderssoni	7.815	30.934	170	297	21.166
Protomyctophum normani	7.447	21.329	109	283	28.3
Electrona subaspera	7.052	11.961	41	268	14.105
Protomyctophum chilensis	6.368	11.126	60	242	10.083
Paradiplospinus antarcticus	6.078	11.352	39	231	13.588
Protomyctophum sp.1	5.973	11.056	47	227	17.461
Gymnoscopelus sp.2	4.421	11.908	70	168	15.272
Protomyctophum sp.2	4.289	11.198	58	163	11.642
Lampanyctus sp. 7	3.921	14.728	88	149	18.625
Vinciguerria attenuata	3.736	9.928	52	142	10.142
Symbolophorus sp2	3.447	8.55	38	131	6.238
Symbolophorus sp1	3.236	7.144	30	123	8.2
Myctophum phengodes	3.105	9.302	43	118	23.6
Ceratoscopelus warmingii	3.105	10.854	58	118	16.857
Lampanyctus sp.5	3.052	8.183	43	116	8.285
Lampanyctus sp.4	2.921	5.354	19	111	7.4
Scopelarchus guenteri	2.526	4.004	16	96	4.8
Stomias spp.	2.447	5.82	29	93	5.812
Electrona sp.2	2.421	5.054	25	92	7.076
Stemonosudis sp.	2.368	3.73	16	90	3.75
Diogenichthys atlanticus	2.21	10.423	64	84	16.8
Diaphus ostenfeldi	1.789	4.844	20	68	11.333
Argyropelecus hemigimnus	1.684	7.311	40	64	16

. Cont.

Astronesthes sp.	1.421	6.512	40	54	9
Melamphaeidae gen sp.	1.421	2.138	7	54	3.375
Bathylagus sp.	1.289	3.237	15	49	5.44
Lampanyctus sp.1	1.21	3.129	13	46	7.666
Lampanyctus sp. 6	1.026	3.42	20	39	5.571
Lampanyctus sp. 2	0.815	1.798	8	31	2.583
Notolepis coatsi	0.789	2.996	16	30	10
Protomyctophum sp.3	0.763	2.685	13	29	7.25
Hirundichthys rondeletti	0.631	2.294	11	24	8
Hygophum bruuni	0.552	1.082	4	21	2.333
Diaphus sp.	0.5	1.555	7	19	3.8
Sternoptyx sp.	0.421	1.03	5	16	2
Vinciguerria nimbaria	0.421	2.595	16	16	16
Oxyporamphus micropteryx	0.394	2.433	15	15	15
Scopelosaurus cf. herwigi	0.368	1.282	6	14	3.5
Lampanyctus sp.3	0.368	1.964	12	14	7
Diplophos rebainsi	0.342	1.097	6	13	2.166
Electrona carlsbergi	0.315	1.016	5	12	3
Dolopichthys longicornis	0.289	1.784	11	11	11
Acanthochaenus luetkeni	0.289	1.784	11	11	11
Lampanyctus sp.8	0.263	1.622	10	10	10
Ichthyococcus sp.	0.236	0.675	3	9	1.8
Protomyctophum sp.4	0.236	1.024	6	9	3
Hygophum sp.	0.21	0.843	5	8	1.6
Epigonus sp.	0.21	0.703	3	8	2
Bentalbella elongata	0.157	0.369	1	6	1
Gonichthys barnesi	0.157	0.678	4	6	2
Loveina sp.	0.157	0.593	3	6	1.5
Cypselurus sp.	0.157	0.973	6	6	6
Danaphos oculatus	0.131	0.811	5	5	5
Paralepididae spp.	0.131	0.664	4	5	2.5
Woodsia meyerwaardeni	0.108	0.393	2	4	1.333

Cont.

Chauliodus sp.	0.105	0.648	4	4	4
Macroparalepis sp.	0.105	0.508	3	4	2
Evermanella balbo	0.105	0.383	2	4	1.333
Electrona sp.1	0.105	0.508	3	4	2
Melanocetus johnsoni	0.105	0.508	3	4	2
Caristius sp.	0.105	0.388	2	4	1.333
Dolichopteryx longipes	0.078	0.358	2	3	1.5
Lampris sp.	0.078	0.273	1	3	1
Trachurus sp.	0.078	0.358	2	3	1.5
Opisthoproctus soleatus	0.052	0.324	2	2	2
Scopelarchus sp.	0.052	0.324	2	2	2
Electrona antarctica	0.052	0.324	2	2	2
Apogonidae gen sp.	0.052	0.324	2	2	2
Bramidae gen sp.	0.052	0.226	1	2	1
Bathylagus antarcticus	0.026	0.162	1	1	1
Maurolicus sp.	0.026	0.162	1	1	1
Hygophum reinhardi	0.026	0.162	1	1	1
Lampadena sp.	0.026	0.162	1	1	1
Prognichthys sp	0.026	0.162	1	1	1
Zeidae gen.sp.	0.026	0.162	1	1	1
Chiasmodon sp.	0.026	0.162	1	1	1
Dysalotus sp.	0.026	0.162	1	1	1
Naucrates ductor	0.026	0.162	1	1	1
Nomeidae gen. sp.	0.026	0.162	1	1	1

Table 3. Calculations of diversity indices and evenness of 38 ichthyoplankton samples taken on the 34th cruise of R/V "Dmitrii Medeleev" with samples groups outlined by cluster analysis.

Group	Sample	Total number of species	Total number of larvae	Shannon-Wiener diversity (H')	Evenness (J')
antarctic - antarctic polar front	1	4	189	0.55	0.27
	2	3	101	0.59	0.37
	3	5	40	1.54	0.66
	mean	**4.00**	**110.00**	**0.89**	**0.43**
Southern part of the Subantarctic	4	13	101	3.03	0.82
	5	18	196	3.38	0.81
	6	15	151	3.54	0.91
	7	21	317	3.21	0.73
	8	17	268	3.32	0.81
	9	19	234	3.28	0.77
	10	20	319	3.37	0.78
	11	19	181	3.28	0.77
	30	14	70	3.35	0.88
	31	17	188	3.42	0.84
	32	11	238	2.66	0.77
	33	9	109	2.55	0.80
	34	13	337	2.85	0.77
	35	18	236	3.35	0.80
	mean	**16.00**	**210.36**	**3.18**	**0.80**

Table 3. Cont.

Northern part of the Subantarctic	12	9	48	2.13	0.33	0.67
	13	15	47	3.33	0.15	0.85
	14	9	54	2.75	0.18	0.87
	15	15	40	3.51	0.11	0.90
	17	15	493	0.60	0.87	0.15
	27	12	21	3.37	0.11	0.94
	28	10	308	0.68	0.83	0.21
	29	15	373	2.11	0.36	0.54
	mean	**12.50**	**173.00**	**2.31**	**0.36**	**0.64**
Subtropical Convergence	16	8	727	0.31	0.93	0.10
	18	13	305	2.73	0.25	0.74
	19	22	335	2.70	0.32	0.61
	20	22	701	2.36	0.34	0.53
	21	15	112	2.70	0.29	0.69
	22	16	131	3.16	0.16	0.79
	23	22	141	3.68	0.11	0.83
	24	14	90	2.68	0.26	0.70
	25	19	124	3.21	0.17	0.75
	26	12	47	3.09	0.14	0.86
	36	10	57	2.85	0.17	0.86
	37	22	123	4.04	0.07	0.91
	mean	**16.25**	**241.08**	**2.79**	**0.27**	**0.70**
Subtropical Gyre(38)		16	515	1.53	0.56	0.38

ble 4. Two-way sample by species table resulting from TWINSPAN classification.
lues denote categories of abundance: 1: 0-0.03, 2: 0.03-0.06, 3: 0.06-1.0, 4:1.0-1.5,
1.5-5.0 specimens/1000m3

		Subtropical Gyre	Subtropical Convergence	Subantarctic northern	Subantarctic southern	Antarctic-Antarctic Polar Front	
			<-><---------->	<------>	<---------->	<->	
			3 223112212223	22111112	3333 11 33		
			8 137890264566	89472357	01458967014523	123	
ciguerria nimbaria	13	5	----------	--------	----------	---	000000
pelarchus sp.	20	2	----------	--------	----------	---	000000
ophum reinhardi	41	2	----------	--------	----------	---	000000
selurus sp.	67	5	----------	--------	----------	---	000000
coetus obtusirostris	68	6	----------	--------	----------	---	000000
gnichthys sp.	70	2	----------	--------	----------	---	000000
poramphus micropteryx	71	5	----------	--------	----------	---	000000
asmodon sp.	77	2	--2-------	--------	----------	---	000000
alotus sp.	78	2	----------	--------	----------	---	000000
eidae gen. sp.	84	2	----------	--------	----------	---	000000
aphos oculatus	6	-	4---------	--------	----------	---	000001
uliodus sp.	15	-	--4-------	--------	----------	---	000001
ronesthes sp.	17	-	42-6362----	--------	----------	---	000001
alepididae spp.	25	-	4-----2-----	--------	----------	---	000001
rmanella balbo	26	-	522-------	--------	----------	---	000001
atoscopelus warmingii	27	5	6-5426----	--------	----------	---	000001
phus ostenfeldi	28	-	-5466-5--5--	--------	----------4--	---	000001
phus sp.	29	5	-2--235----	--------	----------	---	000001
genichthys atlanticus	30	6	554--3----	--------	----------	---	000001
ichthys barnesi	36	-	-24-----2---	--------	----------	---	000001
panyctus sp.1	44	-	-25555--5---	--------	----------	---	000001
panyctus sp.3	46	-	25---------	--------	----------	---	000001
eina sp.	52	-	--2-23----	--------	----------	---	000001
tophum phengodes	53	-	-65-656----	--------	----------	---	000001
opichthys longicornis	65	-	--5-------	--------	----------	---	000001
nocetus johnsoni	66	-	--3-22----	--------	----------	---	000001
ndichthys rondeletti	69	-	---545----	--------	----------	---	000001
thochaenus luetkeni	72	-	----5------	--------	----------	---	000001
gonidae gen sp.	76	-	--2--2----	--------	----------	---	000001
istius sp.	80	-	--2-22----	--------	----------	---	000001
trates ductor	81	-	----2------	--------	----------	---	000001
tiguerria attenuata	12	2	5555565-4523	-2------	-2----------	---	000010
toparalepis sp.	24	-	-----3--2---	--------	----------	---	000010
pris sp.	63	-	22-------2--	--------	----------	---	000010
thyococcus sp.	11	-	-32-----22-2	--------	----------	---	000011
dae gen.sp.	74	-	1-------1---	--------	----------	---	000011
hidae gen sp.	79	-	----2---2--	--------	----------	---	000011
thurus sp.	82	-	---------2-2	--------	----------	---	000011
hias spp.	16	-	26-5465-23--	--------	-2-4-2--2223-2	---	00010
polophorus spl	61	-	2546655--225	-2-2----	-2-4--------2-	---	00010
pphum sp.	39	-	--4---2-----	-2----2-	----------	---	00011
anyctus sp.4	47	-	-25555---654	----2322	---2----4-----	---	00011
beresox saurus	64	-	-2-6665666--	66-6----	----------	---	00011
ophos rebainsi	7	-	----------23-	-5---2--	-2-2----------	---	00100
onosudis sp.	23	-	-5--22-25554	2522-322	25-3-32222-2--	---	00100
anyctus sp. 6	49	-	-------3-64-	---4---3	2-------2-----	---	00100
elarchus guenteri	19	-	44453623222-	24525552	---4----------	---	001010
anyctus sp. 2	45	-	-2-33---5-2-	-2--2--2	----2--252----	---	001010
otone spp.	5	5	555--542222-	--52-444	----55245455--	---	001011
omyctophum chilensis	55	-	-2-552-54255	5-552252	25--554566----	---	001011
onus sp.	75	-	----3-------	---3-2--	--------2----	---	001011
anyctus sp.5	48	-	------22325-	36-2----	3356---2-2----	---	0011
mphaeidae gen sp.	73	3	-25---22---4	---2-24-	----453543-1--	---	0011
chopteryx longipes	3	-	----------	------22	----------	---	01000
thoproctus soleatus	4	-	----------	-----2--	----------	---	01000
trona sp.1	34	-	----------	--3---2-	----------	---	01000
adena sp.	43	-	----------	-2------	----------	---	01000
hoptyx sp.	10	-	4----------	--22--22	-------2--31--	---	01001
phum bruuni	40	-	------2--3--	-4-2----	-2--23-22-----	---	01001
anyctus sp. 7	50	-	---------3-5	-6------	56-2--5-3-----	---	01001
trona subaspera	33	-	---------24--	2-3-34-2	4666655565-25-	---	010100
sia meyerwaardeni	14	-	----------	------2-	-----2---2----	---	010101
albella elongata	18	-	----------	-----2--	-----2-2-211--	---	010101
trona sp.2	35	-	----------	----643-	---5525554-122	---	010101
myctophum bolini	54	-	----------	5-442223	545-66-6665666	---	010101
diplospinus antarcticus	83	-	----------	5542-22-	3325556666-6--	---	010101
blicus sp.	9	-	----------	--------	--2----------	---	010110
elosaurus cf. herwigi	21	-	----------	---2----	2-54----------	---	010110
oscopelus sp.1	37	-	----------	26--23--	25666666655664	---	010110
anyctus sp.8	51	-	----------	--------	---5----------	---	010110
myctophum normani	56	-	----------	-------2	566645-----465	---	010110
myctophum sp.1	57	-	----------	----4---	555-6-54566565	---	010110
myctophum sp.2	58	-	2---------	--------	53523-55453566	---	010110
myctophum sp.4	60	-	----------	--------	--52------1---	---	010110
olophorus sp2	62	-	----------4	22------	346655552---2-	---	010110
topelecus hemigimnus	8	-	----------	------2-	----66---2----	---	010111
rona carlsbergi	32	-	----------	--------	-------2--24-3	---	010111
myctophum sp.3	59	-	----------	--------	----2-55----4-	---	010111
lagus sp.	2	-	----------	--------	-----2555235--	1-2	011
scopelus sp.2	38	-	----------	--------	--6-55555-4555	--4	011
lagus antarcticus	1	-	----------	--------	----------	--1	1
epis coatsi	22	-	----------	--------	----------	554	1
rona antarctica	31	-	----------	--------	----------	23-	1
tichthys anderssoni	42	-	----------	--------	----------1---	655	1

Fig. 3 Dendrogram of sample groups derived from classification with the program TWINSPAN.

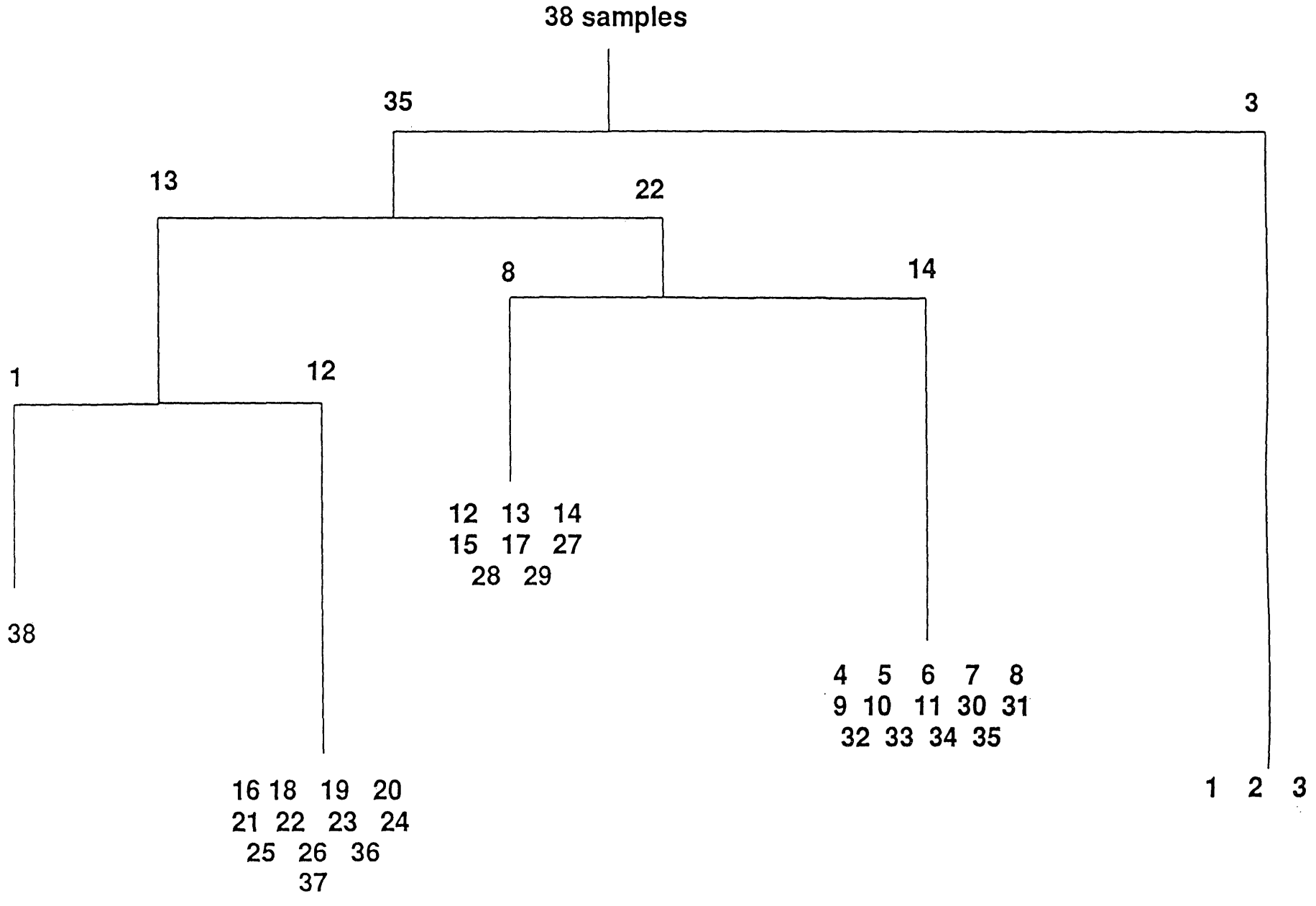
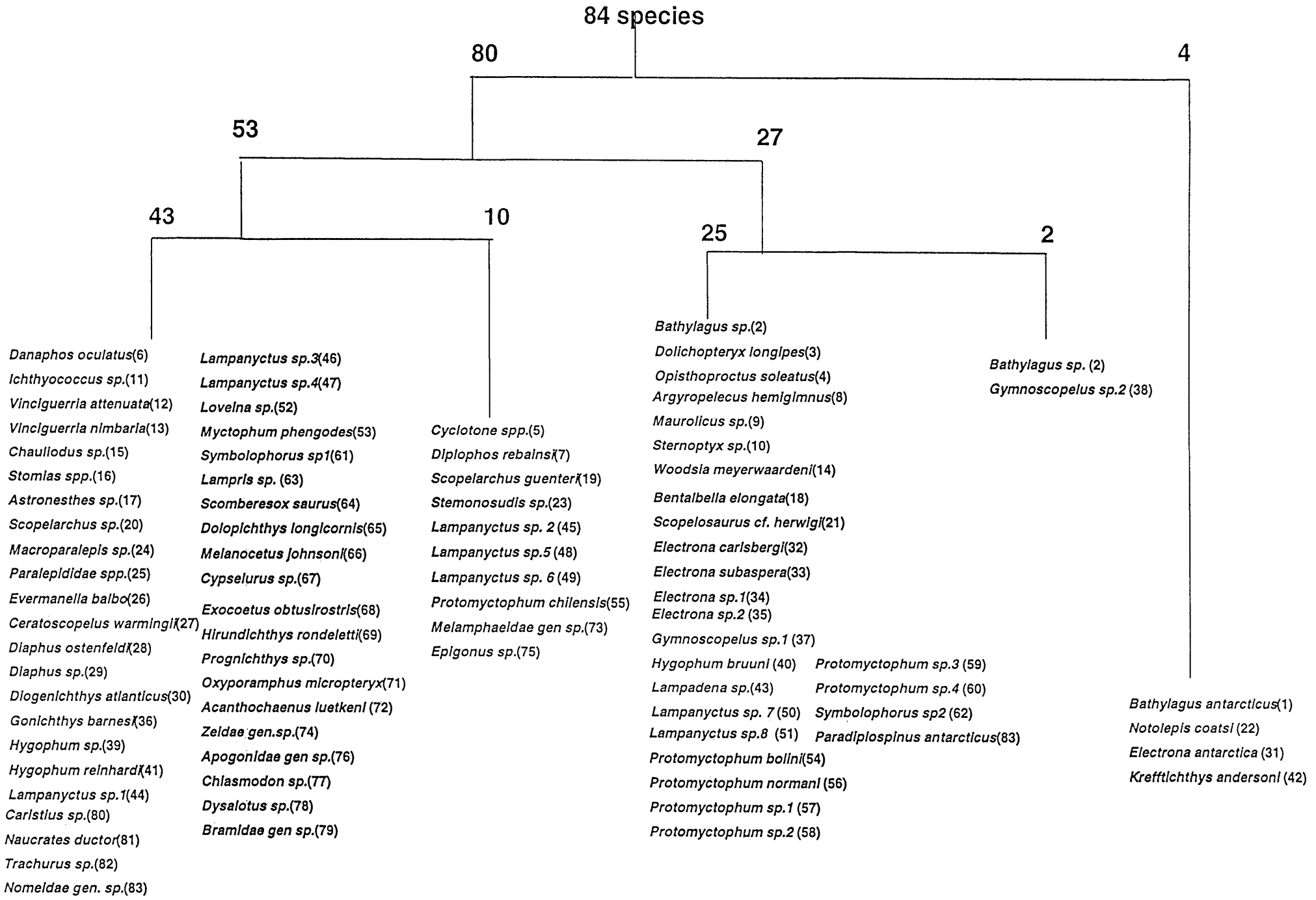

38 samples
35
3
13
22
8
14
1
12
38
12 13 14
15 17 27
28 29
4 5 6 7 8
9 10 11 30 31
32 33 34 35
16 18 19 20
21 22 23 24
25 26 36
37
1 2 3

Fig. 4 Dendrogram of species groups derived from classification with the program TWINSPAN.

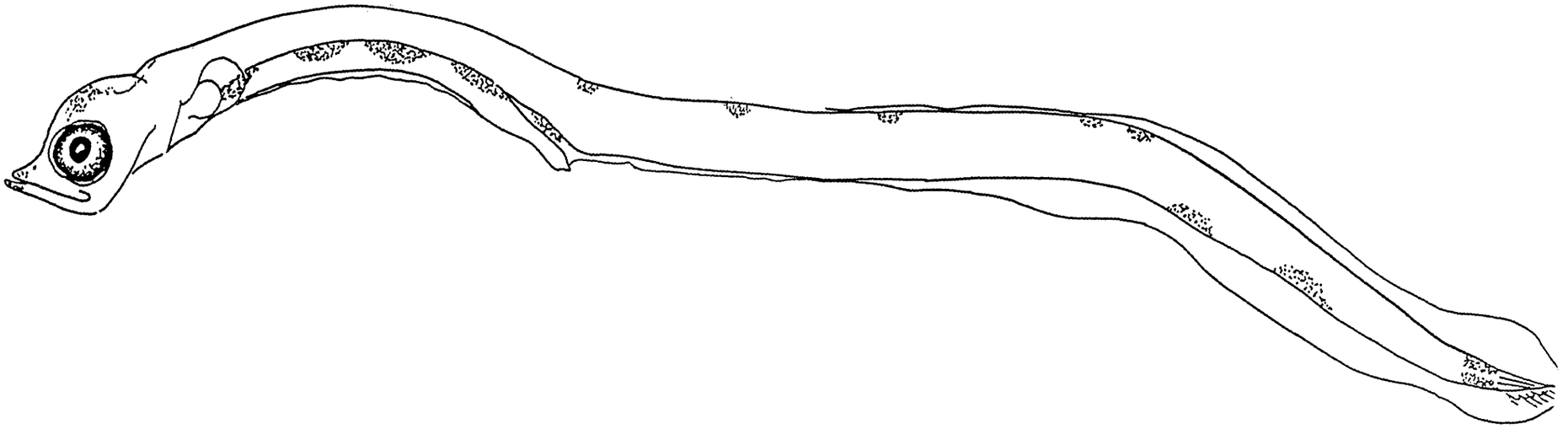

84 species
80
4
53
27
43
10
25
2
Danaphos oculatus(6)
Ichthyococcus sp.(11)
Vinciguerria attenuata(12)
Vinciguerria nimbaria(13)
Chauliodus sp.(15)
Stomias spp.(16)
Astronesthes sp.(17)
Scopelarchus sp.(20)
Macroparalepis sp.(24)
Paralepididae spp.(25)
Evermanella balbo(26)
Ceratoscopelus warmingii(27)
Diaphus ostenfeldi(28)
Diaphus sp.(29)
Diogenichthys atlanticus(30)
Gonichthys barnesi(36)
Hygophum sp.(39)
Hygophum reinhardti(41)
Lampanyctus sp.1(44)
Carlstius sp.(80)
Naucrates ductor(81)
Trachurus sp.(82)
Nomeidae gen. sp.(83)
Lampanyctus sp.3(46)
Lampanyctus sp.4(47)
Lovelna sp.(52)
Myctophum phengodes(53)
Symbolophorus sp1(61)
Lampris sp. (63)
Scomberesox saurus(64)
Dolopichthys longicornis(65)
Melanocetus johnsoni(66)
Cypselurus sp.(67)
Exocoetus obtusirostris(68)
Hirundichthys rondeletti(69)
Prognichthys sp.(70)
Oxyporamphus micropteryx(71)
Acanthochaenus luetkeni (72)
Zeidae gen.sp.(74)
Apogonidae gen sp.(76)
Chlasmodon sp.(77)
Dysalotus sp.(78)
Bramidae gen sp.(79)
Cyclotone spp.(5)
Diplophos rebainsi(7)
Scopelarchus guenteri(19)
Stemonosudis sp.(23)
Lampanyctus sp. 2 (45)
Lampanyctus sp.5 (48)
Lampanyctus sp. 6 (49)
Protomyctophum chilensis(55)
Melamphaeidae gen sp.(73)
Epigonus sp.(75)
Bathylagus sp.(2)
Dolichopteryx longipes(3)
Opisthoproctus soleatus(4)
Argyropelecus hemigimnus(8)
Maurolicus sp.(9)
Sternoptyx sp.(10)
Woodsia meyerwaardeni(14)
Bentalbella elongata(18)
Scopelosaurus cf. herwigi(21)
Electrona carlsbergi(32)
Electrona subaspera(33)
Electrona sp.1(34)
Electrona sp.2 (35)
Gymnoscopelus sp.1 (37)
Hygophum bruuni (40)
Lampadena sp.(43)
Lampanyctus sp. 7 (50)
Lampanyctus sp.8 (51)
Protomyctophum bolini(54)
Protomyctophum normani (56)
Protomyctophum sp.1 (57)
Protomyctophum sp.2 (58)
Protomyctophum sp.3 (59)
Protomyctophum sp.4 (60)
Symbolophorus sp2 (62)
Paradiplospinus antarcticus(83)
Bathylagus sp. (2)
Gymnoscopelus sp.2 (38)
Bathylagus antarcticus(1)
Notolepis coatsi (22)
Electrona antarctica (31)
Krefftichthys andersoni (42)

anderssoni, separated in the first TWINSPAN division by species (Fig. 4), and also *Bathylagus sp.* and *Gymnoscopelus sp.*2 separated in the third division of TWINSPAN.

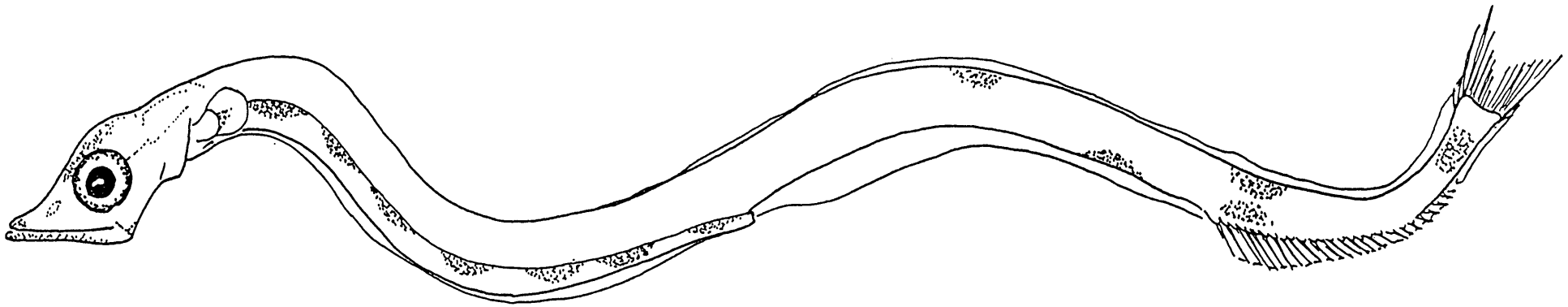
The second TWINSPAN division separated 22 subantarctic samples from 13 samples taken in Subtropical Convergence and subtropical waters. 22 subantarctic samples were separated in the third TWINSPAN division into two groups - roughly northern and southern subantarctic waters. However, sample 17 taken in Subtropical Convergence waters was included in the northern subantarctic group. Most of the species in 8 samples representing northern part of the subantarctic were also common for clusters of Subtropical Convergence and southern part of the subantarctic. The most common and abundant species in this group were *Stemonosudis sp.* (Fig. 5), *Scopelarchus guenteri, Cyclothone sp.* and *Protomyctophum chilensis* (Table 4).

Fourteen samples representing southern part of the subantarctic were dominated by myctophids *Electrona subaspera*, *Electrona sp.2* (Fig. 6), *Gymnoscopelus sp.1*, *Protomyctophum bolini*, *P. normani*, *P. sp.*1, *P. sp.*2, *P. sp.*3, *P. sp.*4, (Fig. 7, 8, 9, 10) *Symbolophorus sp.*2 (Fig. 11), scopelarchid *Bentalbella elongata*, gempylid *Paradiplospinus antarcticus* (see chapter 1). Larvae of *Gymnoscopelus sp.*2 and *Bathylagus sp.* were grouped together in small cluster that broke off in the third TWINSPAN division on species. Included in this cluster were also species that were quite common in northern subantarctic waters and waters of Subtropical Convergence as can be seen in species groups (Table 4), such as paralepidid *Stemonosudis sp.*, gonostomatid *Cyclothone sp.*, and myctophids *Hygophum bruuni, Lampanyctus sp.*2 (Fig. 12), *L. sp.* 4 (Fig. 13), *L. sp* 5, *L. sp.*6 (Fig. 14), *Protomyctophum chilensis*, *Symbolophorus sp.*1 (Fig.

Fig. 5 *Stemonosudis sp.* : a) 16.0 mm SL, b) 24.0 mm SL; c) 49.0 mm SL.



a



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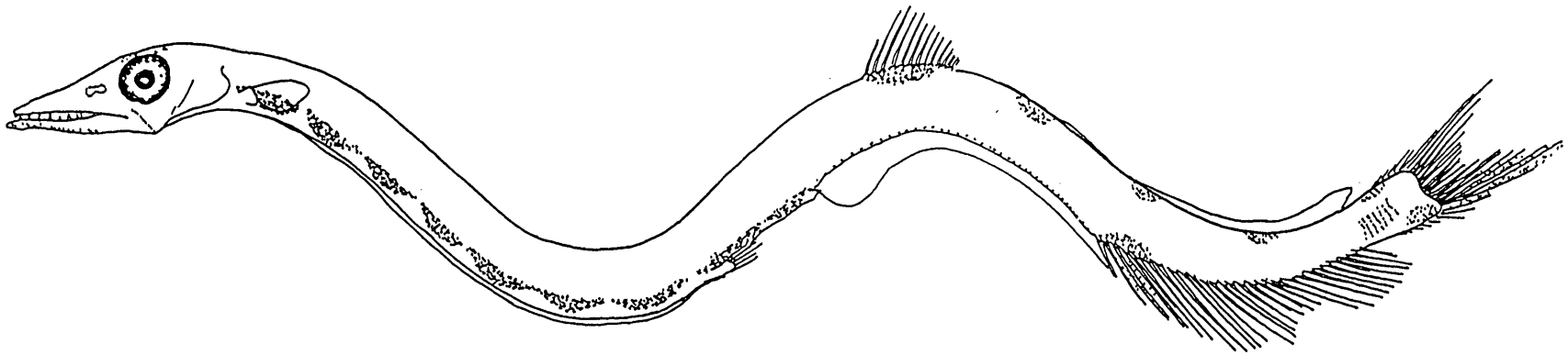


c

Fig. 6 *Electrona sp.* 2, 17.6 mm SL.

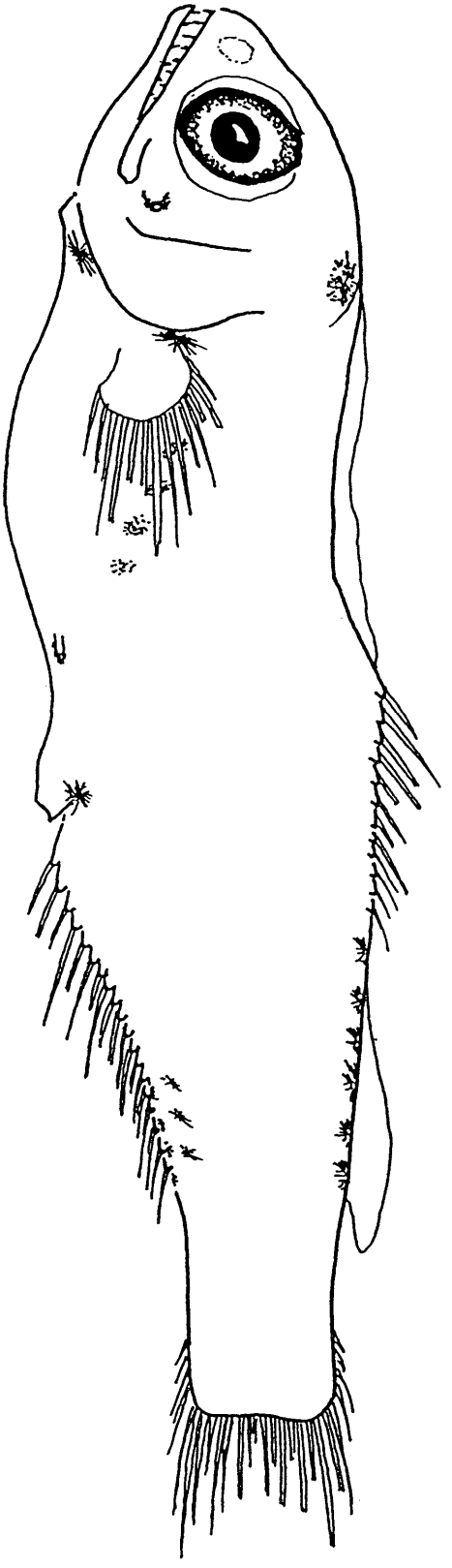


Fig. 7 *Protomyctophum sp.*1, 18.2 mm SL.

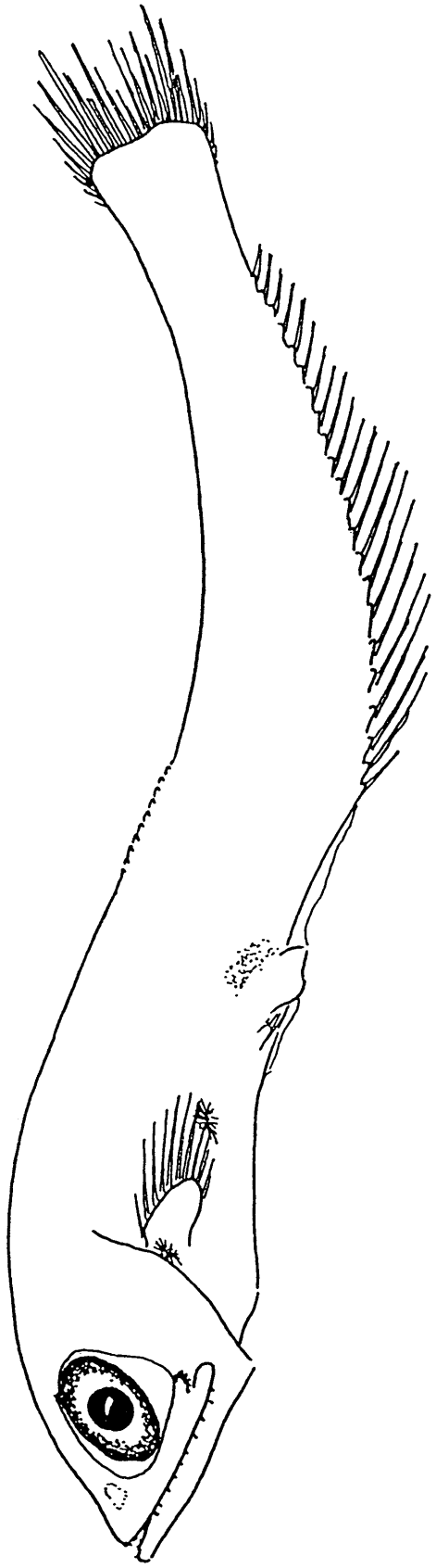


Fig. 8 *Protomyctophum sp.*2, 16.3 mm SL.

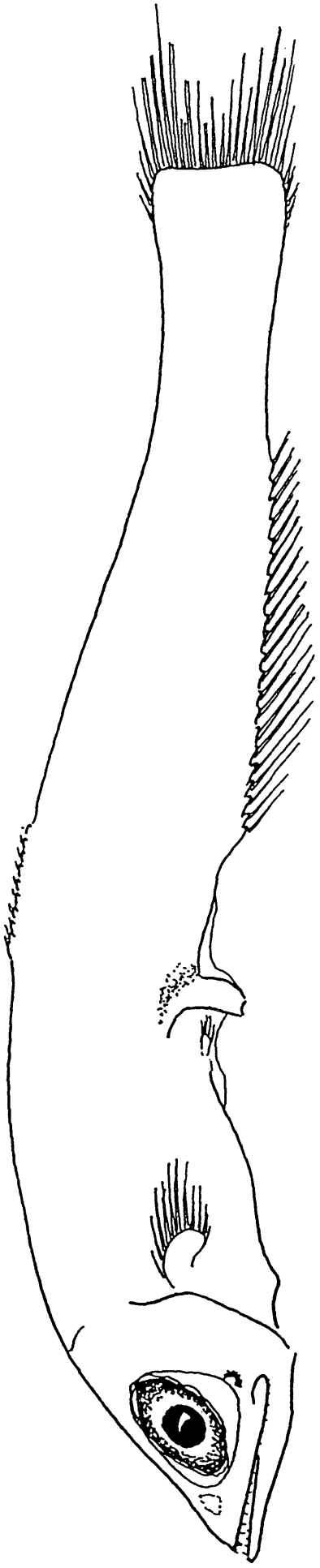


Fig. 9 *Protomyctophum sp.*3, 18.3 mm SL.

Fig. 10 *Protomyctophum sp.*4, 14.0 mm SL.

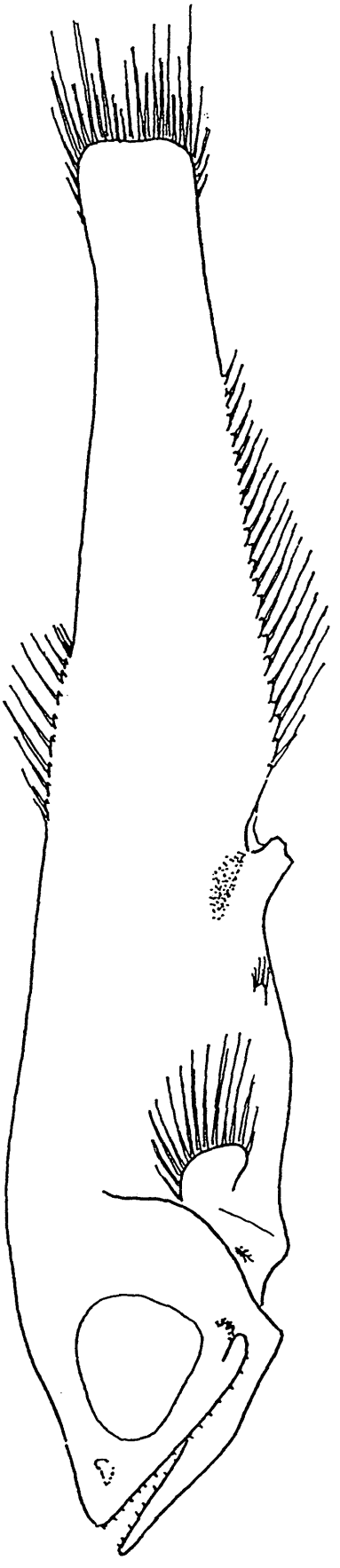


Fig. 11 *Symbolophorus sp.* 2, 13.0 mm SL.

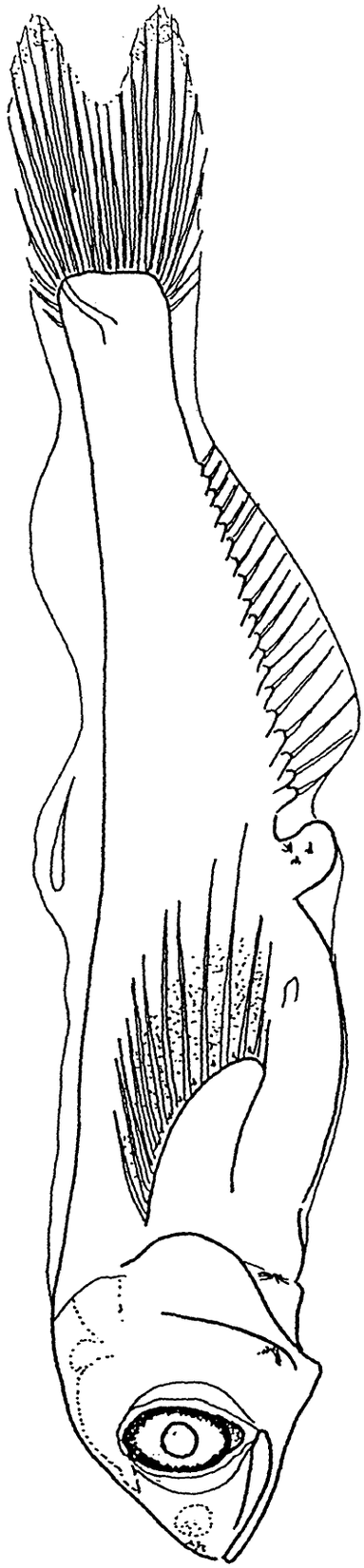


Fig. 12 *Lampanyctus sp.* 2, 11.0 mm SL.

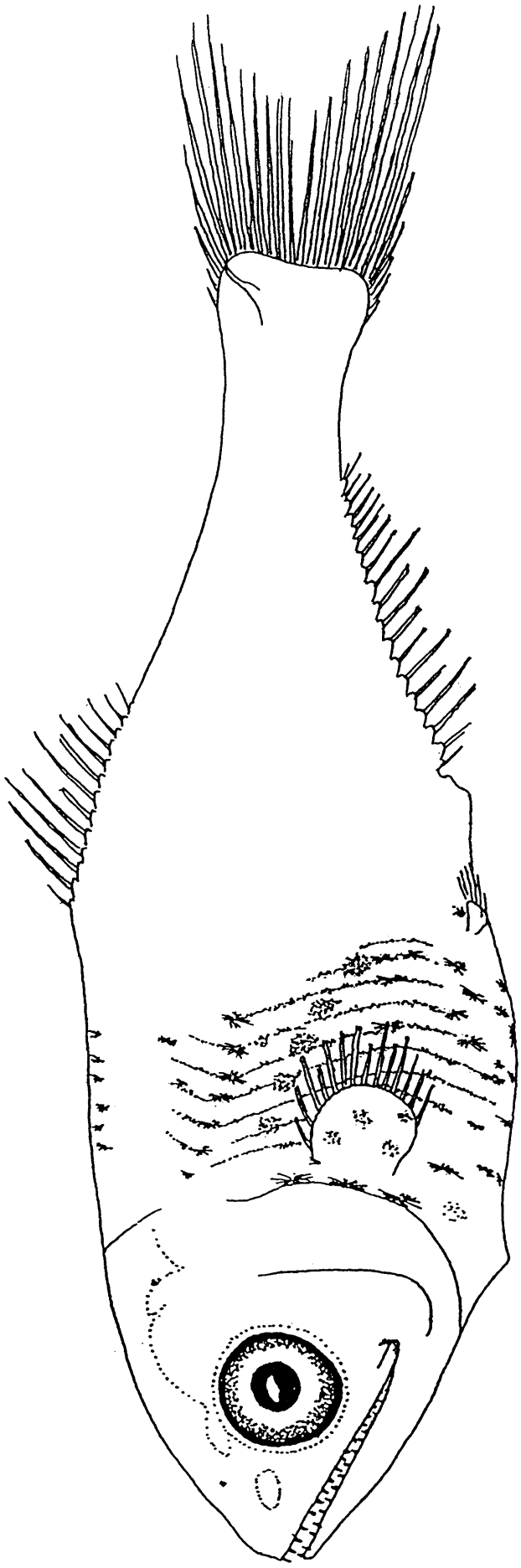
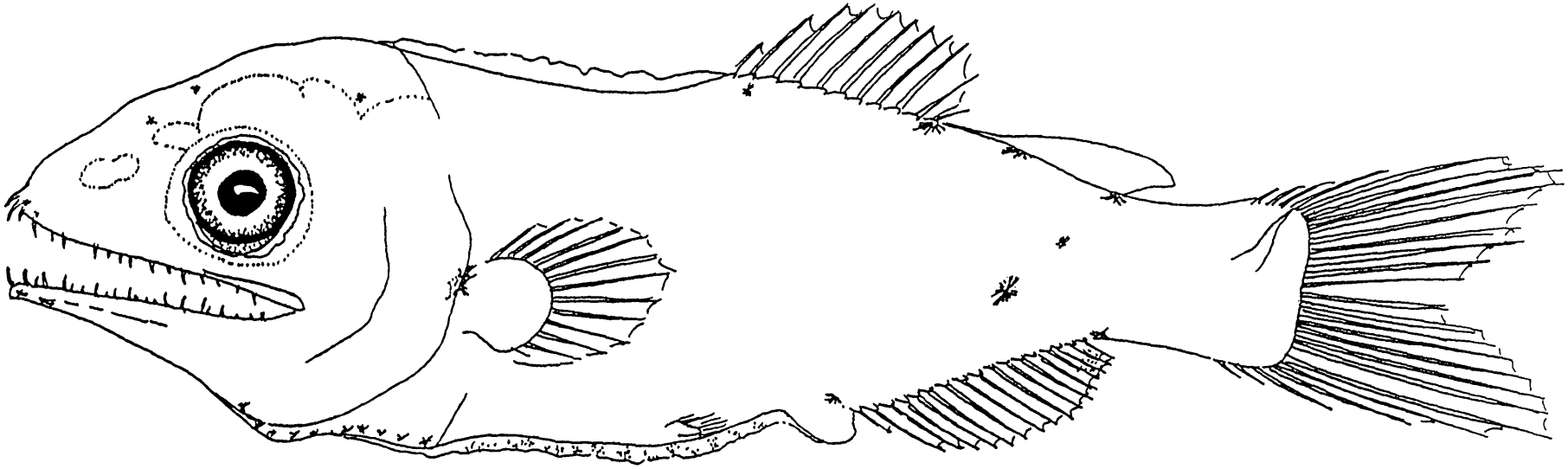


Fig. 13 *Lampanyctus sp.* 4, a) 10.9 mm SL, b) 17.2 mm SL.



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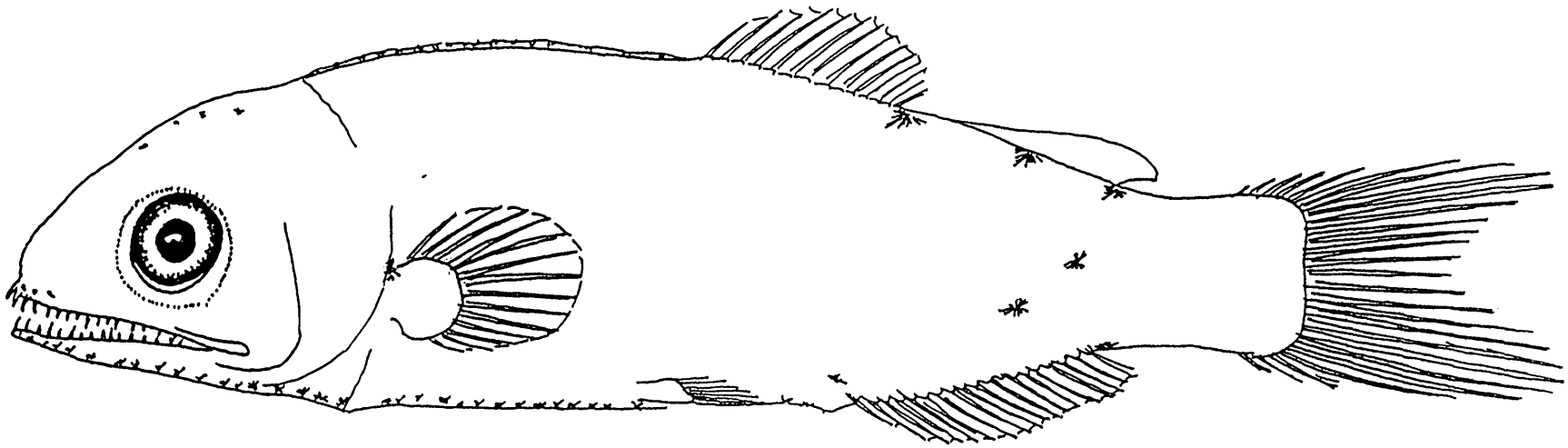


b

Fig. 14 *Lampanyctus sp.* 6, 13.8 mm SL.

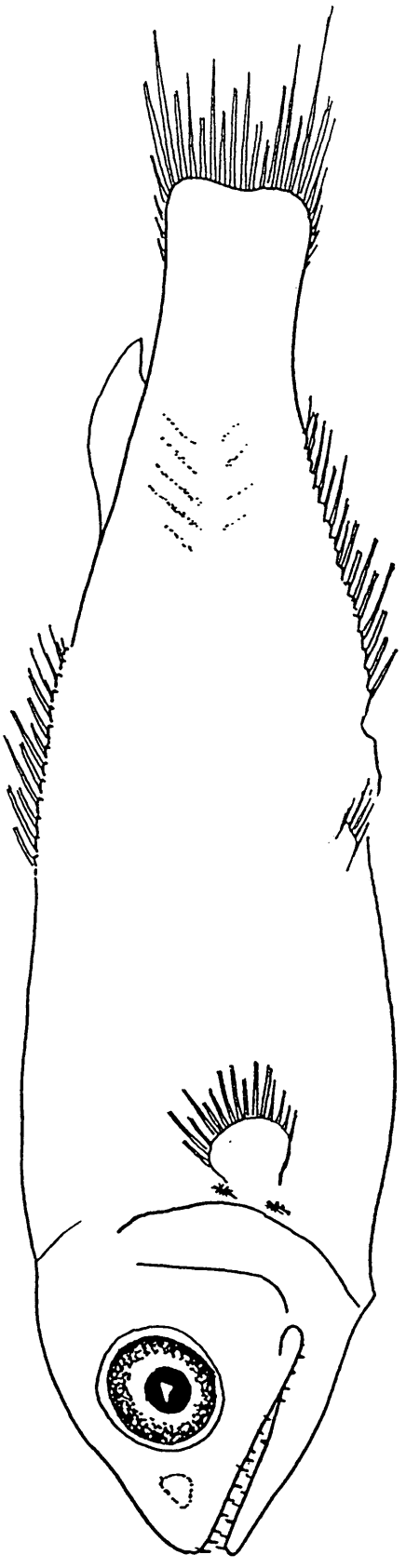


Fig. 15 *Symbolophorus sp.* 1, 12.2 mm SL.

15), stomiatid *Stomias sp.* and larvae of melamphaeids. A number of less abundant species were also represented in this cluster including gonostomatid *Diplophos rebainsi*, *Woodsia meyerwaardeni*, sternoptychid *Sternoptyx sp.*, notosudid *Scopelosaurus cf. herwigi*, and myctophid *Electrona carlsbergi.*

The third TWINSPAN division also separated sample 38 taken on the periphery of subtropical gyre from 10 samples taken within or just outside the Subtropical Convergence and samples 26 and 37 taken in the northern subantarctic waters. Sample 38 was dominated by such typical representatives of subtropical ichthyofauna as larvae of flying fishes - *Cypselurus sp.*, *Exocoetus obtusirostris*, *Prognichthys sp.*, oxyporamphid *Oxyporamphus micropteryx* and also included representatives of subtropical and tropical waters such as chiasmodontids *Chiasmodon sp.*, *Dysalotus sp.* (Fig. 16), photichthyid *Vinciguerria nimbaria*, myctophids *Ceratoscopelus warmingii*, *Diaphus sp.*, *Diogenichthys atlanticus*, *Hygophum reinhardii.* Ten samples from the Subtropical Convergence were dominated by photichthyid *Vinciguerria attenuata*, astronesthid *Astronesthes sp.* (see chapter 2), myctophids *Ceratoscopelus warmingii*, *Diaphus ostenfeldi*, *Diogenichthys atlanticus*, *Diaphus sp.*, *Lampanyctus sp. 1* (Fig. 17), *Lampanyctus sp. 4*, *Myctophum phengodes*, *Symboophorus sp.1*, and very abundant scomberesocid *Scomberesox saurus.* Some rarer representative of tropical-subtropical ichthyofauna were also present in this cluster including photichthyid *Ichthyococcus sp.*, evermannellid *Evermanella balbo*, myctophids *Loveina sp.*, *Gonichthys barnesi* (Fig. 18), stephanoberycid *Acanthochaenus luetkeni*, lamprid *Lampris sp.*, and larvae of ceratioid anglerfishes *Dolopichthys longicornis* and *Melanocetus johnsoni.*

Fig. 16 *Dysalotus sp.*, 18.0 mm SL.

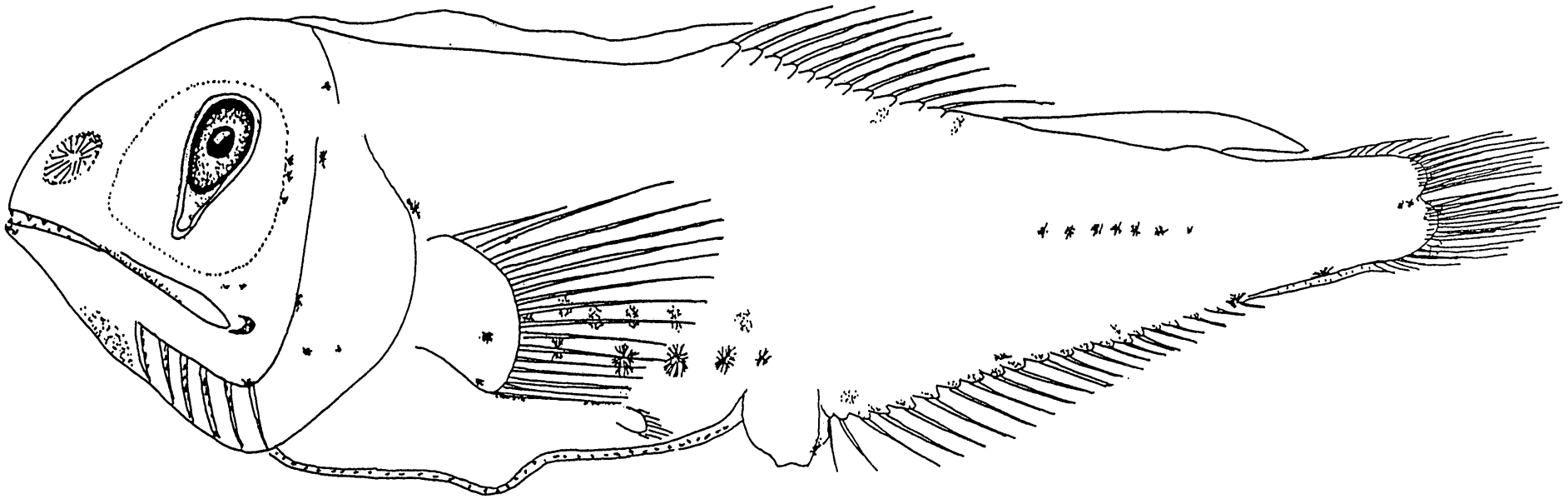
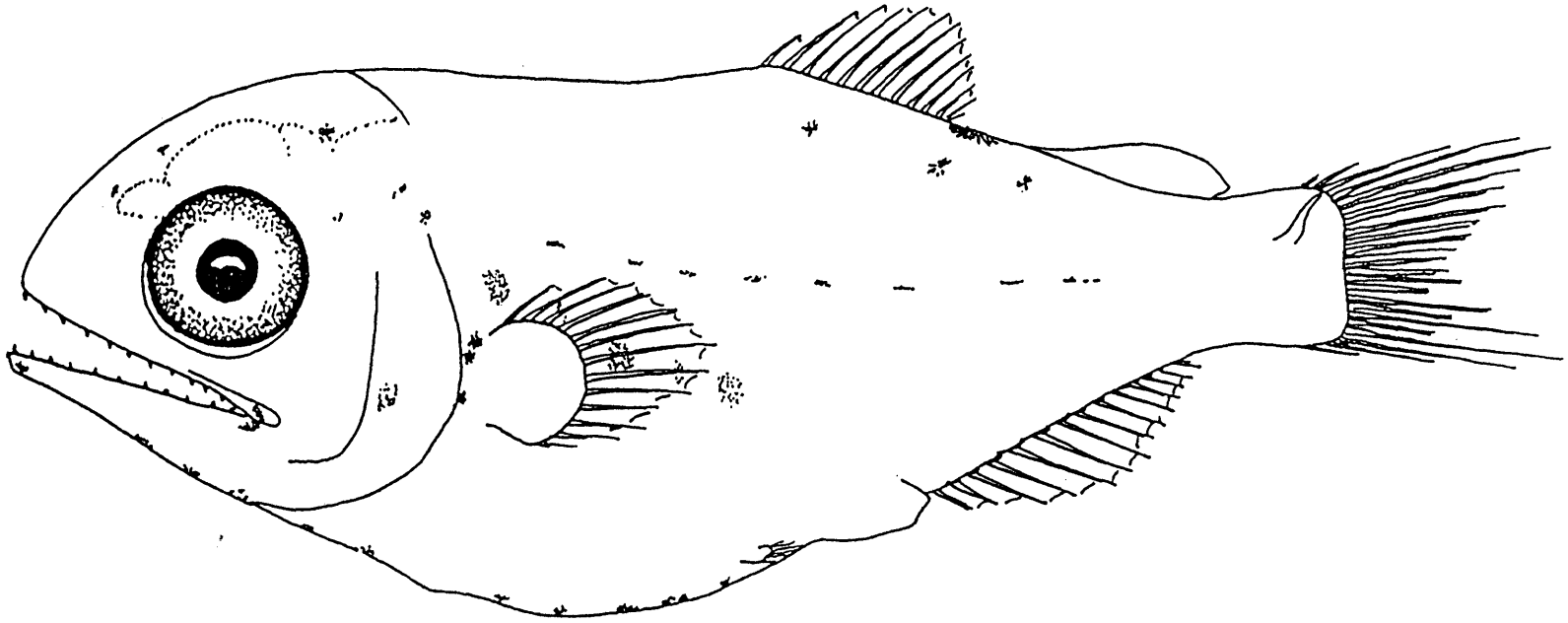
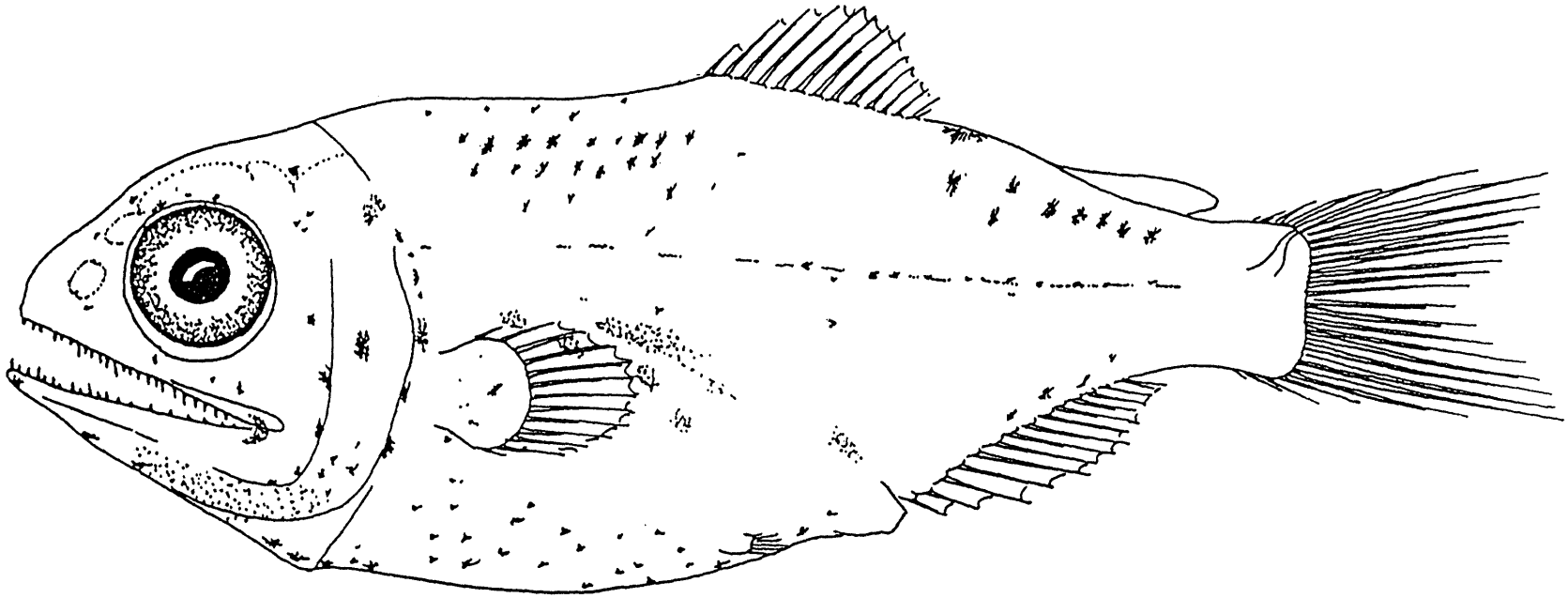


Fig. 17 *Lampanyctus sp.* 1, a) 7.5 mm SL, b) 9.7mm SL.

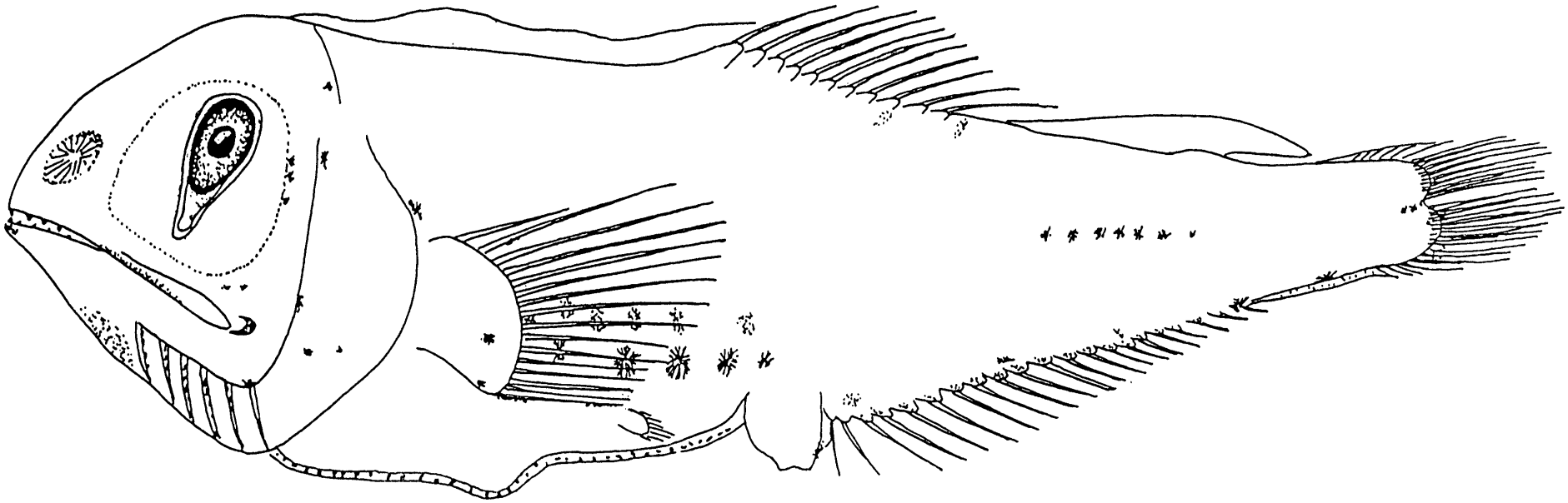


a



b

Fig. 18 *Gonichthys barnesi*, 12.7 mm SL.



Ordination

Detrended Correspondence Analysis (DCA)

The DCA separated samples into three primary groupings along the first axis (Fig. 19). The southernmost stations - samples 1,2 and 3 associated with antarctic- antarctic polar front waters are grouped on the left side of the axis 1, while northernmost, such as sample 38 from South Pacific Subtropical Gyre is positioned on the right extreme. Samples from subantarctic waters and waters of Subtropical Convergence are grouped in the middle of the plot. The first axis of DCA displayed an extremely long gradient of 9.42 SD, i.e. more then two complete turnovers of species (Hill, 1980). The first two axes of species-environment biplot based on species abundances accounted for 14.5 and 5.8 % of the variation and have eigenvalues 0.916 and 0.364 respectively (Table 5). According to interset correlations of environmental variables and ordination axes, the first axis clearly expressed latitudinal gradient, with positive correlation to surface salinity, temperature on all levels and a strong negative correlation to latitude (Table 6a). It is more difficult to interpret the distribution of sample scores along second axis, since all interset correlations for this axis are very small. Thus, it appear that no single environmental variable can be separated as a major influencing factor for this axis.

In DCA plot for species (Fig. 20), *Bathylagus antarcticus*, *Notolepis coatsi*, *Electrona antarctica* and *Krefftichthys andersoni*, found at southernmost stations, are grouped on the left side of the first axis. Larvae of subtropical species, such as *Chiasmodon sp.*, *Dysalotus sp.*, *Cypselurus sp.*, *Exocoetus obtusirostris*, *Prognichthys sp.*, *Oxyporamphus micropterix*, myctohids *Diogenichthys atlanticus, Hygophum*

Fig. 19 Ordination diagram of the 38 samples using Detrended Correspondence Analysis (DCA).

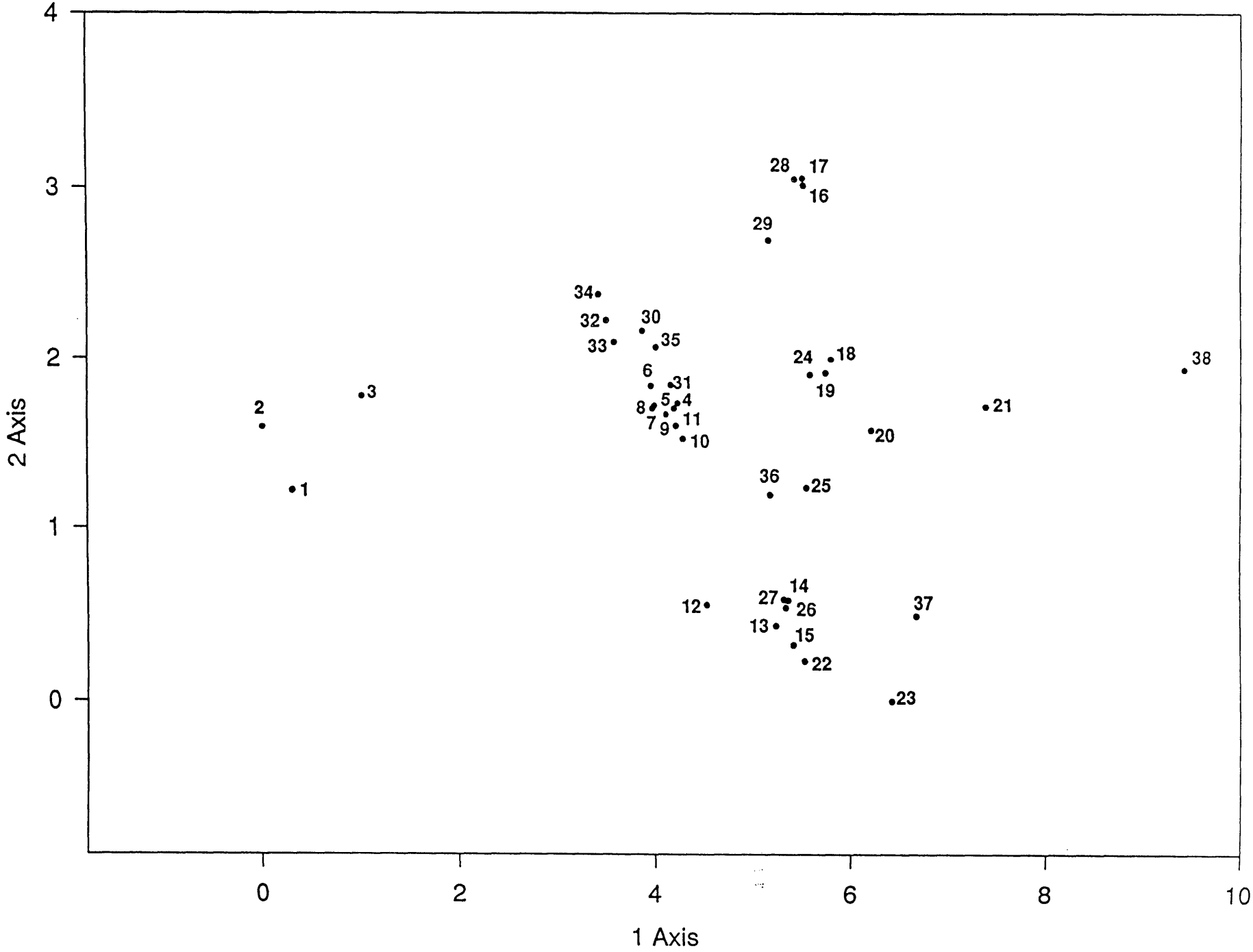

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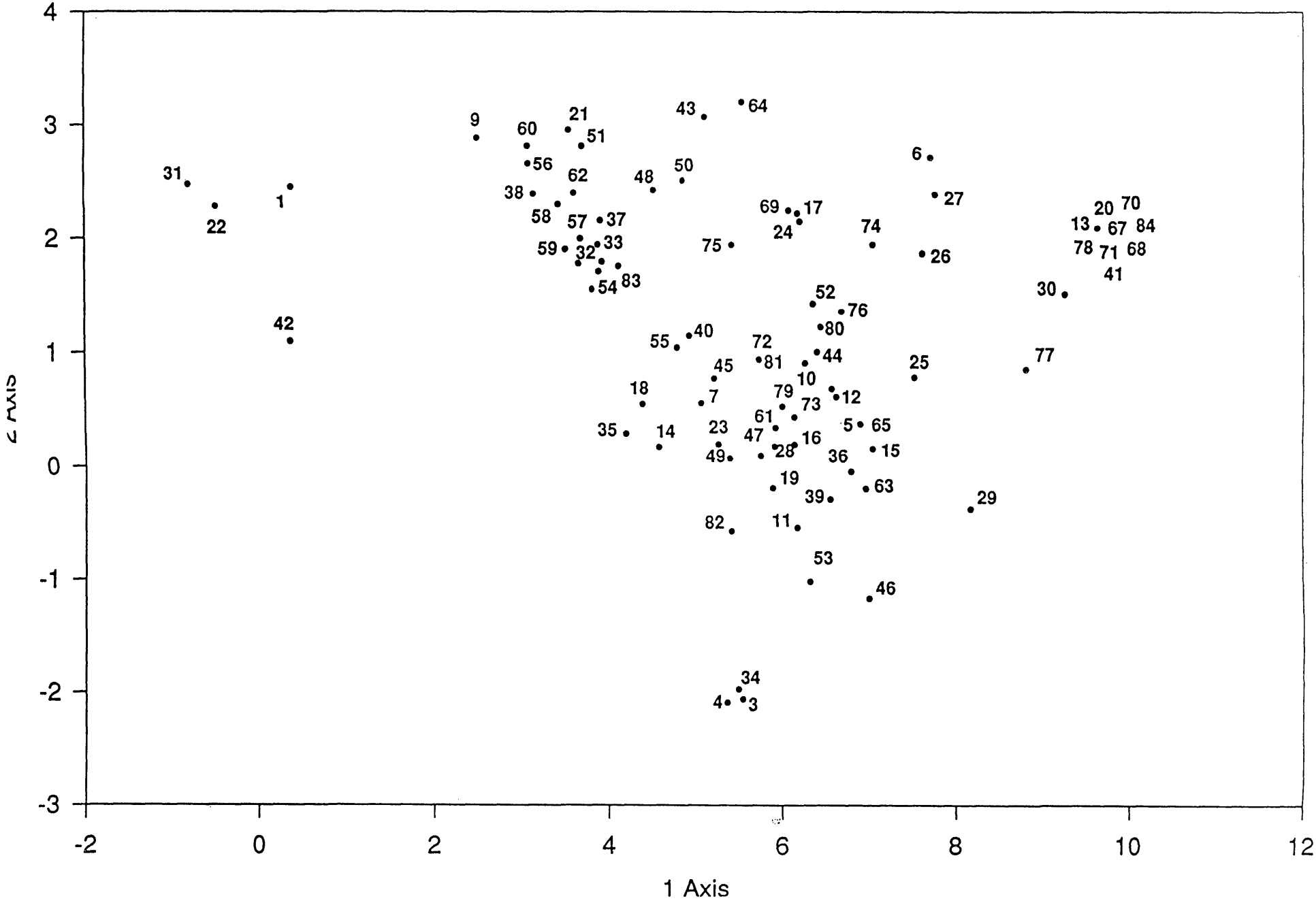
Table 5. Results of Detrended Correspondence Analysis (DCA).

Axes	1	2	3	4
Eigenvalues	0.916	0.363	0.215	0.159
Length of gradient	9.424	3.051	2.500	2.904
Species-environment correlations	.989	.895	.933	.883
Cumulative percentage variance of species data species-environment relationships	 14.5 19.7	 20.3 27.7	 23.7 .0	 26.2 .0
Sum of all unconstrained eigenvalues	6.305			
Sum of all canonical eigenvalues	4.360			
Total inertia	6.305			

Table 6. Correlation matrix relating DCA axes to environmental variables (= interset correlations of environmental variables with axes) and fraction of variance in environmental data that is extracted by each axis. a - DCA with all samples; b - DCA with samples 1, 2, 3 and 38 excluded.

	a		b	
	Axis 1	Axis 2	Axis 1	Axis2
Temperature 0m	.93	-.09	0.78	-0.22
Temperature 50m	.71	-.003	0.58	-0.01
Temperature 100m	.71	.05	0.54	0.01
Temperature 150m	.72	.03	0.50	-0.04
Temperature 200m	.70	.03	0.42	-0.02
Salinity 0m	.78	.01	0.04	-0.54
Salinity 50m	.24	.02	0.34	0.06
Salinity 100m	.24	.02	0.33	0.06
Salinity 150m	.24	.021	0.33	0.06
Salinity 200m	.24	.02	0.33	0.06
DO 0m	.01	.01	0.23	0.08
DO 50m	.06	.02	0.30	0.07
DO 100m	.073	-.00	0.28	0.07
DO 150m	.029	-.01	0.24	0.06
DO 200m	.02	-.04	0.21	0.05
Latitude	-.97	.05	-0.88	0.16
Longitude	.16	-.03	0.09	-0.14
Fraction of variance	.28	.001	0.19	0.03

Fig. 20 Ordination diagram of 84 ichthyoplankton species using Detrended Correspondence Analysis (DCA).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3

reinhardi, and some other species including Nomeidae gen. sp., *Scopelarchus sp.*are grouped on the right side of axis 1. Species from subantarctic waters and waters of Subtropical Convergence are positioned in the middle of DCA plot.

The first run of DCA on all samples showed that antarctic-antarctic polar front samples (1, 2, 3) and subtropical sample (38) are very distinct in their composition from the majority of the samples and clearly represent a distinct assemblages. To refine the ordination results and obtain better resolution for subantarctic samples and samples from Subtropical Convergence, a new DCA was applied to the data set without samples 1, 2, 3 and 38. The results of this DCA for samples are shown in Fig. 21. Two major sample groups are formed along the first DCA axis. Samples from Subtropical Convergence are positioned on the right extreme of DCA plot having very similar scores on the first axis but showing broad variation in scores on the second axis. Subantarctic samples group on the left side of the plot, showing most variation in scores primarily along the first DCA axis. Samples 28 and 29, taken in subantarctic waters, do not fit with the proposed water mass division. These samples show high scores for both first and second axes and group with Subtropical Convergence samples. The presence of the very abundant scomberesocid, *Scomberesox saurus* (a species mainly found in the waters of Subtropical Convergence) in this two samples, may have influenced their position. The first two axis of this partial DCA displayed very similar gradients of 4.623 S.D. and 4.601 S.D. respectively. The first two axes of species- environment biplot accounted for 18.3 and 9.6 % variation and had eigenvalues 0.830 and 0.435 (Table 7). According to interset correlations the first axis expressed latitudinal gradient with a positive correlation to temperature and negative

Fig. 21 Ordination diagram of the 38 samples using Detrended Correspondence Analysis (DCA) without sampes 1, 2, 3 and 38.

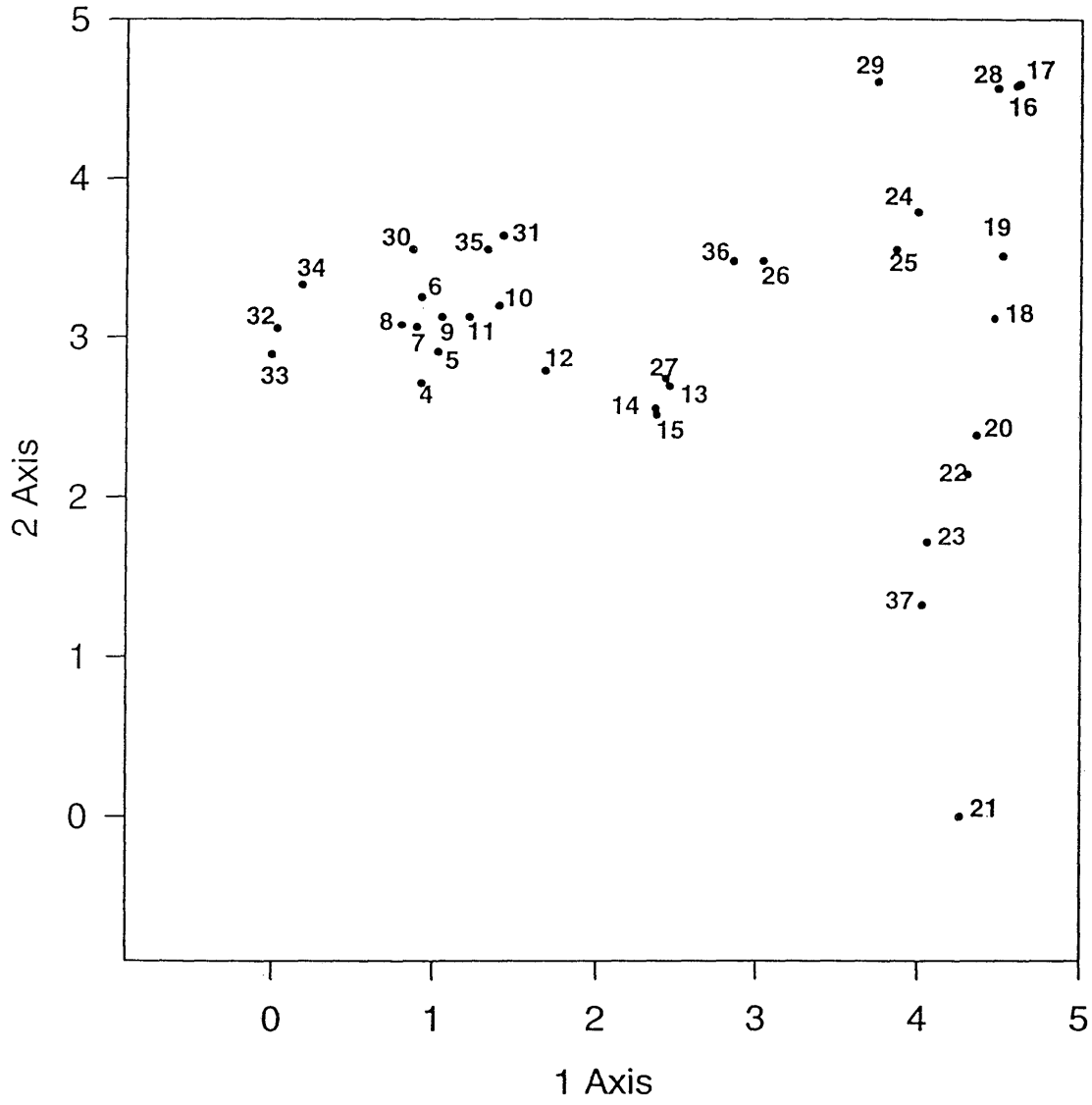
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Table 7. Results of Detrended Correspondence Analysis (DCA) without samples 1, 2, 3 and 38.

Axes	1	2	3	4
Eigenvalues	.830	0.435	0.174	0.095
Lengths of gradient	4.623	4.601	2.218	1.599
Species-environment correlations	0.977	0.966	0.871	0.797
Cumulative percentage variance of species data species-environment relationships	 18.3 25.0	 27.9 40.2	 31.8 .0	 33.9 .0
Sum of all unconstrained eigenvalues	4.5			
Sum of all canonical eigenvalues	3.2			
Total inertia	4.5			

correlation to latitude (Table 6b), which is similar to the results of the first, unconstrained DCA. However, surface salinity at is clearly the major environmental variable used in construction of the second axis (Table 6b) with all other variables being insignificant. Thus, the broad distribution of Subtropical Convergence samples are mainly due to salinity changes.

The results of second DCA for species are shown in Fig. 22. Species, found in subantarctic waters are grouped on the left side of the plot. This group included such species as myctophids *Protomyctophum bolini*, *P. chilensis*, *P.normani*, *P. sp.*1, *P. sp.*2, *P. sp.*3, *P. sp.*4, *Electrona subaspera*, *E. carlsbergi*, *E. sp.*2 , *Symbolophorus sp.* 2, *Gymnoscopelus sp.* 1, *G. sp.* 2, *Lampanyctus sp.*2, *L. sp.* 5, *L. sp.* 7, *Hygophum bruuni*, bathylagid *Bathylagus sp.*, gonostomatid *Diplophos rebainsi*, *Cyclothone sp.*, scopelarchid *Bentalbella elongata*, notosudid *Scopelosaurus cf. herwigi*, paralepidid *Stemonosudis sp.*, gempylid *Paradipospinus antarcticus.* Rare species in this group included myctophids *Electrona sp.* 1 (Fig. 23), *Lampanyctus sp.* 8, photichthyid *Woodsia meierwaardeni*, opisthoproctids *Opistoproctus soleatus*, *Dolichopterix longipes*, gonostomatid *Maurolicus sp.*, sternoptichid *Argyropelecus hemigimnus* and some unidentified melamphaeids.

Species found primarily in the region of Subtropical Convergence are positioned on the extreme right of DCA plot. This group included myctophids *Ceratoscopelus warmingii*, *Diaphus ostenfeldi*, *Diaphus. sp.*, *Diogenichthys atlanticus*, *Symbolophorus sp.* 1, *Lampanyctus sp.* 1, *L. sp.* 3, *L. sp.* 4, *L. sp.* 6, photichthyid *Vinciguerria attenuata,*

Fig. 22 Ordination diagram of ichthyoplankton species using Detrended Correspondence Analysis (DCA) without samples 1, 2, 3 and 38.

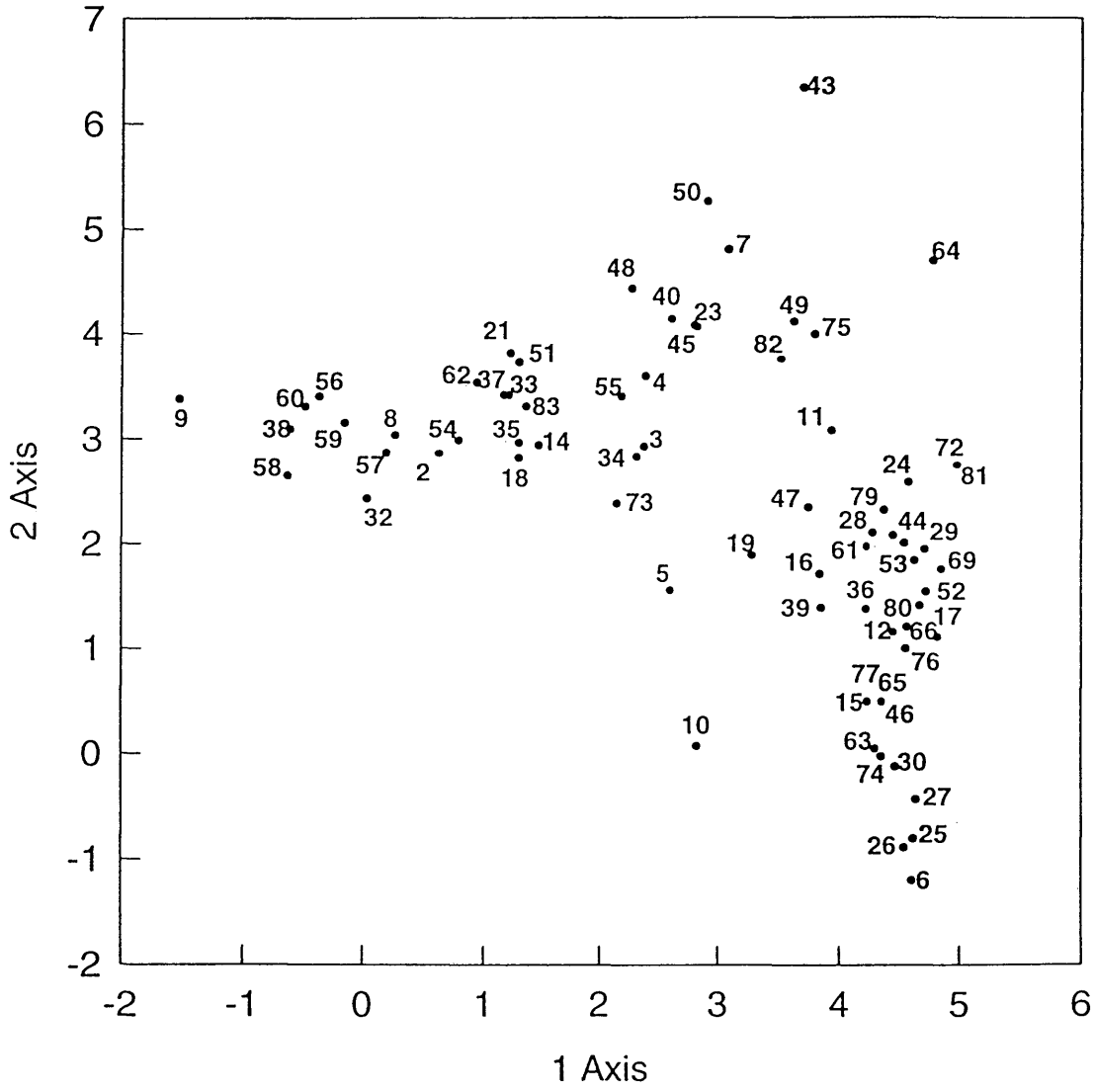
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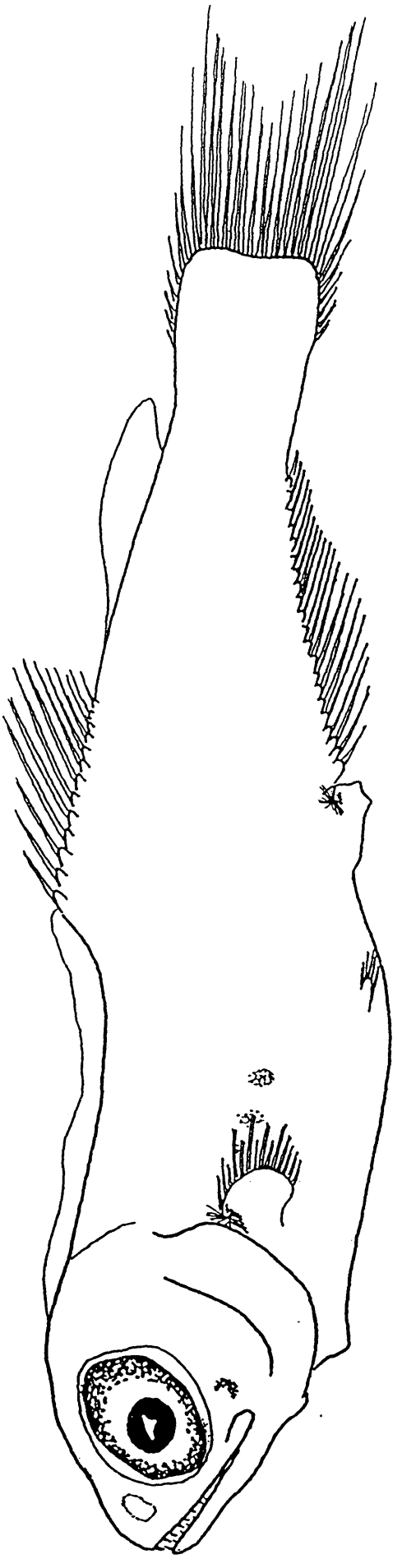
Fig. 23 *Electrona sp.*1, 15.2 mm SL.



Ichthyococcus sp.,stomiatid *Stomias sp.*, astronesthine *Astronestes sp.*, scomberesocid *Scomberesox saurus*, exocoetid *Hirundichthys rondeletti*. Some rare species in this group included myctophids *Lampadena sp.* (Fig. 24), *Loveina sp.*, *Gonichthys barnesi*, chauliodontine *Chauliodus sp.*, gonostomatid *Danaphos oculatus*, evermanellid *Evermanella balbo*, paralepidid *Macroparalepis sp.*, stephanobericid *Acanthochaenus luetckeni*, carangid *Trachurus sp.*, *Naucrates ductor*, lamprid *Lampris sp.*, melanocetid *Melanocetus johnsoni*, chiasmodontid *Chiasmodon sp.*, caristiid *Caristius sp.*, and unidentified larvae of paralepidids, zeids, bramids, apogonids.

Canonical Correspondence analysis (CCA)

The results of CCA for samples are presented in Fig. 25. As in first DCA run, samples taken in antarctic-antarctic polar front waters (1,2,3) occupy the left-hand side of the ordination plot and sample 38 from the subtropical waters is located on the right-hand side of the plot. The remaining samples are positioned in the middle of the plot. Therefore, axis 1 represents a south-north separation of samples. Thirty-four samples in the middle of the plot have very similar scores on the CCA 1. However, these samples form two distinct groups by their scores on the second axis. The group with positive scores comprised samples from subantarctic waters, mostly from its southern part. The group of samples with negative scores on the second axis was composed of samples that came from Subtropical Convergence and samples from northern part of the subantarctic waters.

CCA plot for species (Fig. 26) shows, that antarctic - antarctic polar front species -

Fig. 24 *Lampadena sp.,* 11.2 mm SL.

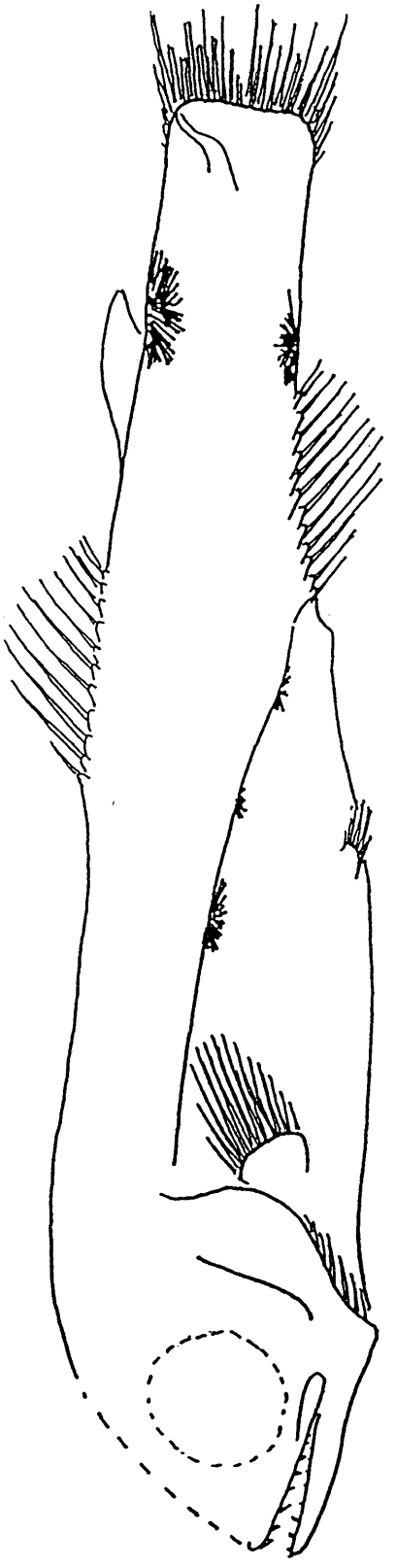


Fig. 25 Ordination diagram of the 38 samples using Canonical Correspondence Analysis (CCA).

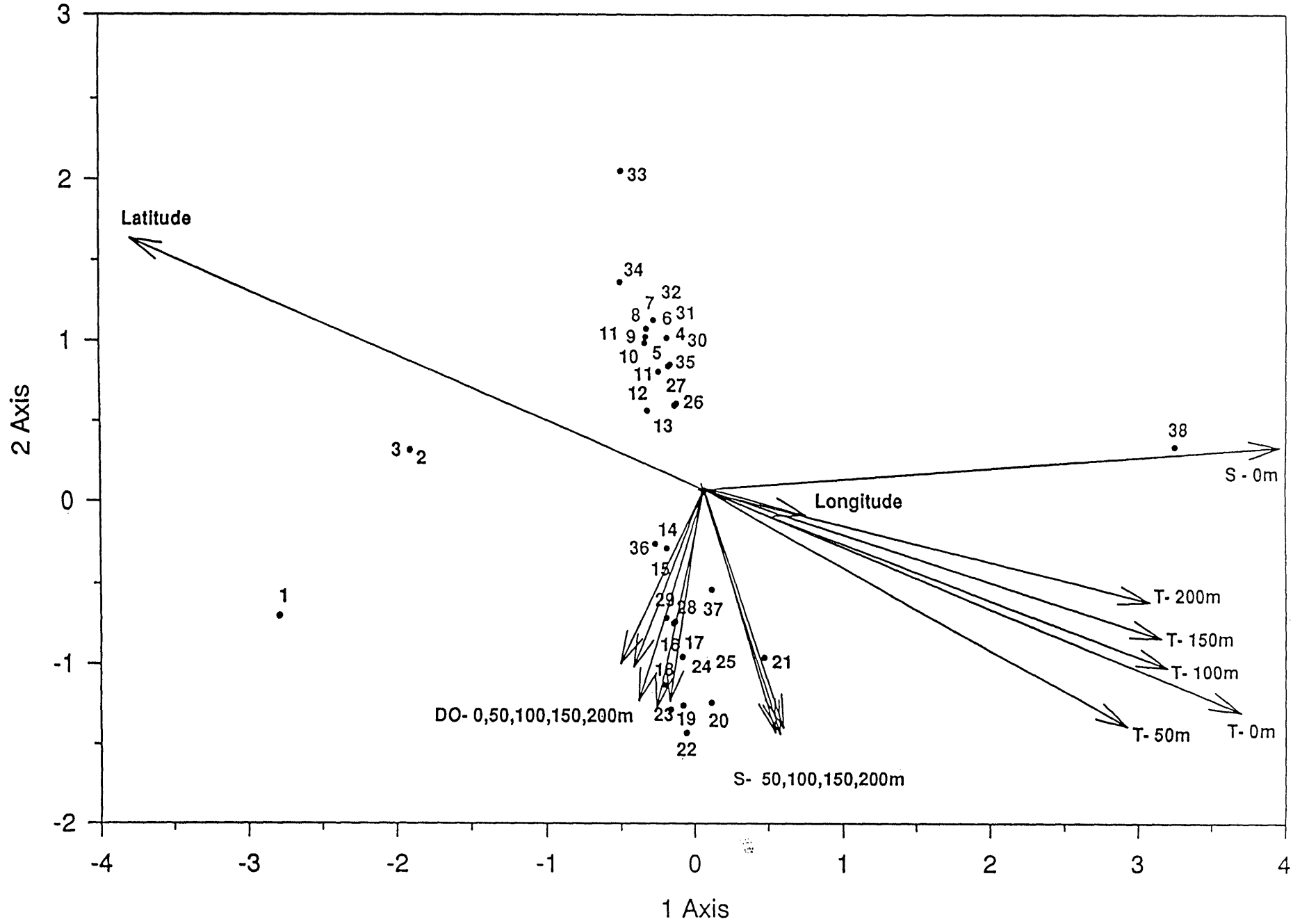
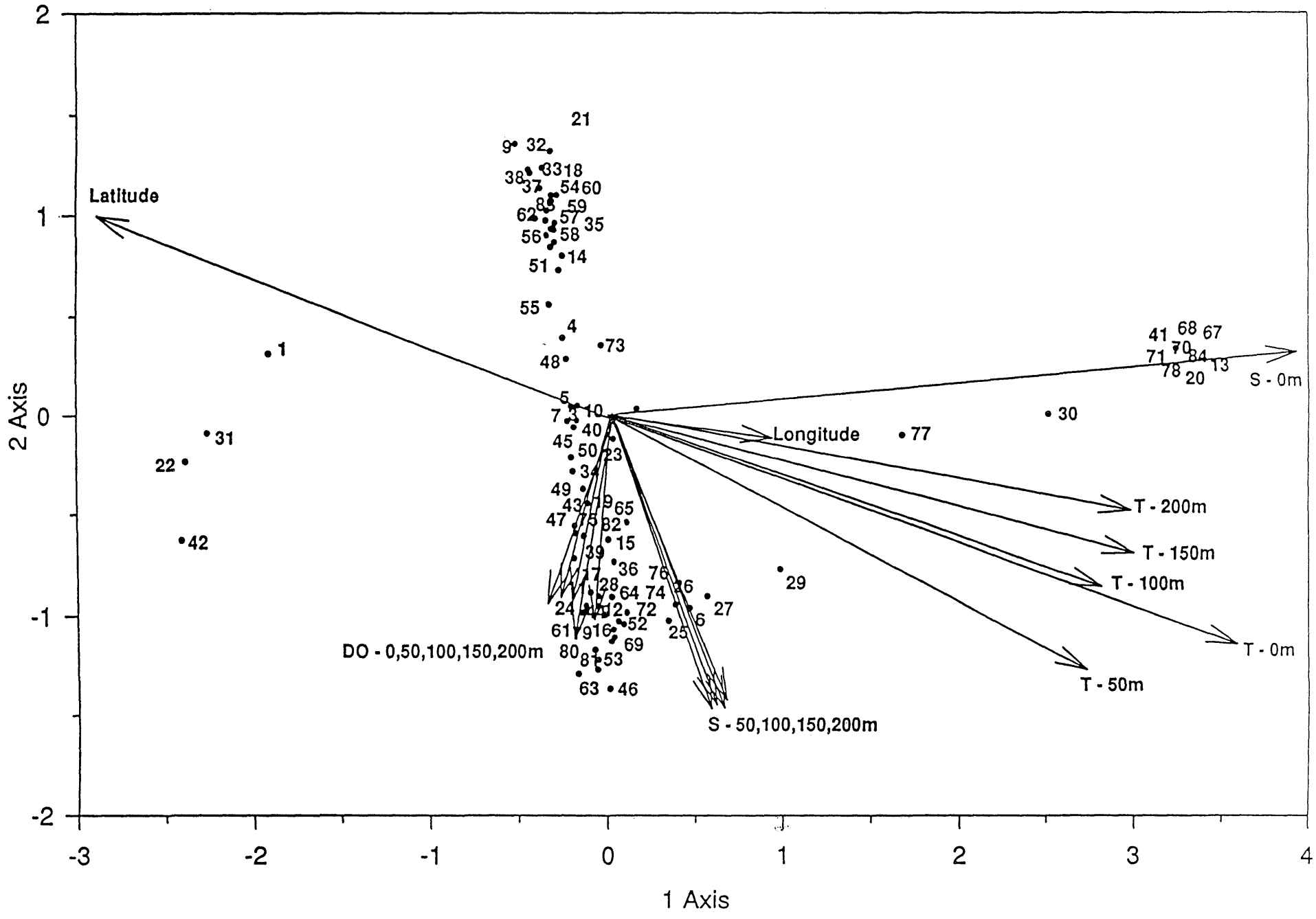

3
2
1
0
-1
-2
2 Axis
-4
-3
-2
-1
0
1
2
3
4
1 Axis
Latitude
Longitude
S - 0m
T- 200m
T- 150m
T- 100m
T- 0m
T- 50m
DO- 0,50,100,150,200m
S- 50,100,150,200m
33
34
32
7
8
6
31
11
9
4
30
10
5
35
11
27
12
26
13
38
3
2
14
36
15
1
29
28
37
16
17
18
24
25
21
23
19
20
22

Fig. 26 Ordination diagram of the 84 ichthyoplankton species using Canonical Correspondence Analysis (CCA).


Latitude
Longitude
S - 0m
T - 200m
T - 150m
T - 100m
T - 0m
T - 50m
DO - 0,50,100,150,200m
S - 50,100,150,200m
1 Axis
2 Axis

Bathylagus antarcticus, *Notolepis coatsi*, *Electrona antarctica* and *Krefftichthys anderssoni* are positioned on the left extreme of the plot, having lowest species scores and species from subtropical waters are grouped on the right extreme. Most of the species in the middle of the plot have very similar scores on the first axis, and as was observed for samples, differ primarily in their scores on the second axis. Thus group of species with higher scores on the second axis consisted of scopelarchid *Bentalbella elongata*, photichthyid *Woodsia meyerwaardeni*, myctophids *Protomyctophum bolini*, *P.normani*, *P. sp.*1, *P. sp.*2, *P. sp.*3, *P.sp.* 4, *Symbolophorus sp.* 2, Gymnoscopelus sp. 1, *G. sp.* 2, *Electrona subaspera*, *E. carlsbergi*, *E. sp.* 2, *Lampanyctus sp.* 7, gempylid *Paradiplospinus antarcticus,* notosudid *Scopelosaurus cf. herwigi*, i.e. species primarily found in the southern part of subantarctic waters (Fig. 26). Group of species with lower scores on second axis included most of the species and was a mixture of species from Subtropical Convergence and subantarctic waters adjacent to convergence. These species included myctophids *Lampanyctus sp.* 3, *L. sp.* 4, *L. Sp.* 6, *L.sp* 7, *Hygophum bruuni*, *Hygophum sp.*, *Diaphus ostenfeldi*, *Diaphus. sp.*, *Ceratoscopelus warmingii*, *Myctophum phengodes*, *Gonichthys barnesi*, *Loveina sp.*, *Lampadena sp.*, photichthyid *Vinciguerria attenuata*, paralepidids *Stemonosudis sp. Macroparalepis sp.*, evermannellid *Evermanella balbo*, scomberesocid *Scomberesox saurus*, gonostomatid *Cyclothone sp.*, *Astronesthes sp.*, *Chauliodus sp.*, *Ichthyococcus sp.*, *Diplophos rebainsi* and some others (Fig. 26). Species from subtropical sample were grouped on the right-hand side of CCA plot.

The results of CCA are shown in Table 8. The first two axes of CCA had

Table 8. Results of Canonical Correspondence Analysis (CCA).

Axes	1	2	3	4
Eigenvalues	0.907	0.787	0.623	0.444
Species-environment correlations	0.996	0.981	0.885	0.882
Cumulative percentage variance of species data species-environment relationships	 14.4 20.8	 26.9 38.9	 36.8 53.2	 43.8 63.3
Sum of all unconstrained eigenvalues	6.305			
Sum of all canonical eigenvalues	4.36			
Total inertia	6.305			

eigenvalues 0.907 and 0.787 respectively. CCA 1 was statistically significant (P = 0.01)(Table 9) and explained 14.4% of the variability in species scores. Arrows in Fig. 23 show the importance of salinity at 0 m, temperature at 0,50,100,150 and 200 m and latitude on CCA 1 (see also interset correlations in Table 10). The species environment-correlation for CCA 1 was 0.99, thus variation in assemblage composition was explained very well by the environmental variables. CCA 2 (P= 0.01) explained 12.5 % of the variability in species scores. The species-environment correlation for CCA 2 was 0.98. CCA 2 scores were highly correlated with latitude, salinity at 50, 100, 150, 200 m, temperature at 0, 50, 100, 150, 200 m, and dissolved oxygen at 0, 50, 100, 150 and 200 m (see interset correlations Table 9). CCA 3 and CCA 4 were shown not to be significant in Monte-Carlo permutation test (P = 0.04; P = 0.09). Multiple regression of site scores (Table 11), demonstrated, that variables, significantly contributing to the model explaining CCA 1 scores were temperature and dissolved oxygen at 150 and 200 m. To predict CCA 2 scores multiple regression incorporated dissolved oxygen at 0 and 200 m and temperature at 200 m. However, as stated in ter Braak (1987) t-values of canonical coefficients are interpretable only when variance inflation factors are low. In my model, variance inflation factors were very high, indicating high intercorrelation of environmental variables with each other, thus t-values of canonical coefficients do not merit interpretation.

Table 9. The results of Monte-Carlo permutation test (performed with 99 unrestricted permutations) on significance of of the fist four axes of CCA.

Axis	Eigenvalue	F-ratio	P-value
1	0.91	3.87	0.01
2	0.79	3.93	0.01
3	0.62	3.59	0.04
4	0.44	3.42	0.09

Table 10. Inter-set correlations of environmental variables with canonical axes, variance explained during forward selection of environmental variables and fraction of variance in environmental data that is extracted by each axis of CCA.

Variables	CCA 1	CCA 2	CCA 3	CCA 4	variance explained
Temperature 0m	0.78	-0.45	-0.03	0.20	0.25
Temperature 50m	0.60	-0.41	0.05	-0.03	0.13
Temperature 100m	0.63	-0.35	0.03	-0.05	0.13
Temperature 150m	0.67	-0.30	0.07	-0.04	0.22
Temperature 200m	0.67	-0.22	0.06	-0.06	0.42
Salinity 0m	0.92	0.08	0.22	0.05	0.66
Salinity 50m	0.14	-0.30	0.09	-0.13	0.08
Salinity 100m	0.14	-0.3	0.09	-0.13	0.0
Salinity 150m	0.13	-0.3	0.09	-0.13	0.14
Salinity 200m	0.13	-0.3	0.09	-0.13	0.03
DO 0m	-0.08	-0.22	0.13	-0.18	0.31
DO 50m	-0.06	-0.28	0.10	-0.15	0.30
DO 100m	-0.03	-0.27	0.12	-0.15	0.15
DO 150m	-0.07	-0.23	0.12	-0.15	0.16
DO 200m	-0.07	-0.20	0.11	-0.13	0.26
Latitude	-0.85	0.45	0.03	-0.16	0.85
Longitude	0.14	-0.04	0.21	-0.04	0.06
Fraction of variance	0.23	0.09	0.01	0.02	

Table 11. Weighted multiple regression of environmental variables on CCA axes, with Student's t-values for canonical coefficients (df = 20 at 5% significance level) and variance inflation factors.

Variables	CCA 1	CCA 2	CCA 3	CCA 4	inflation factor
Temperature 0m	0.4	-0.22	0.87	2.20	155.45
Temperature 50m	0.65	0.20	1.31	0.59	391.76
Temperature 100m	-0.16	-1.21	-0.85	-1.76	1004.28
Temperature 150m	-4.04	-1.31	2.32	1.91	1326.90
Temperature 200m	8.65	6.20	-3.18	-2.51	397.29
Salinity 0m	1.62	0.72	1.19	1.88	57.69
Salinity 50m	0.93	-1.28	-2.00	0.39	3103.13
Salinity 100m	0	0	0	0	.0000
Salinity 150m	0	0	0	0	.0000
Salinity 200m	0	0	0	0	.0000
DO 0m	2.16	-2.13	3.03	-3.49	1120.33
DO 50m	-1.82	1.12	-0.34	1.64	1587.46
DO 100m	0.93	-0.01	0.56	-1.66	3142.85
DO 150m	-2.88	-0.47	-1.17	2.34	1344.20
DO 200m	-1.09	4.65	1.08	3.20	319.07
Latitude	-0.60	1.65	0.58	1.56	213.68
Longitude	-1.95	-0.84	1.12	-2.70	19.78

Comparison of classification and ordination results

The species and stations groups separated in TWINSPAN classification procedure in general correspond well with the results of ordination and the proposed water mass division. The interpretation of division levels of classification is somewhat subjective, since there is no statistical procedure to justify the choice of division levels. Thus, five sample groups formed at the level of third TWINSPAN's division can be described as follows - Antarctic-Antarctic Polar Front Group, southern Subantarctic Group, northern Subantarctic Group, Subtropical Convergence Group and Subtropical Group. Only three groups can be described on the second level of TWINSPAN division - Antarctic-Antarctic Polar Front Group, Subantarctic Group and Subtropical Convergence plus Subtropical Group.

The results of ordination on all samples show, that most of the samples represent rather a continuum than a distinct groups. Samples 1, 2 and 3 (Antarctic - Antarctic Polar Front Group) are well separated in DCA and CCA plots. The same is true for sample 38, representing subtropical community. The majority of the samples (34) from Subantarctic waters and waters of Subtropical Convergence do not form distinct groups along the first - most important axis in ordination. However, clear separation of Subantarctic and Subtropical Convergence samples was attained with removing antarctic-antarctic polar front samples and subtropical sample from DCA. This procedure is well justified, since these four samples are very distinct in their composition, and certainly prevent good resolution within the rest of the samples. Opposite to classification results, this partial DCA did not show any clear separation of northern and southern subantarctic samples.

Thus, it is reasonable to suggest that division of subantarctic waters does not merit interpretation in terms of zoogeography of this area and subantarctic samples may be attributed to one separate zoogeographical domain.

Both direct and indirect analysis showed the prevailing influence of temperature at all levels, salinity at 0 m and latitude on the first axis in ordination (Table 6, 9). However as can be seen from interset correlations, latitude was the variable imposing major influence on the first axis in DCA, while in direct analysis salinity was the variable with largest interset correlation value.

DISCUSSION

Comparison of a present study with previous works is hampered by the lack of studies analyzing distribution of ichthyoplankton assemblages in a vast area of south-western Pacific. The majority of existing works in the region are descriptive studies on ontogeny of Antarctic fishes (Efremenko, 1979; Kellerman, 1989). Studies on larval distribution and ichthyoplankton assemblages concentrated on species inhabiting the antarctic shelf (Loeb et al. 1993, Kellerman and Schadwinkel, 1991; Kuobbi et al. 1991) and deal mainly with suborder Nothotenioidea - the major composite of the Antarctic shelf.

The use of ichthyoplankton data in describing zoogeographical regions is more difficult to interpret than similar studies on adults, since larvae of particular species have much broader geographical range. As expected, the results of ordination analysis indicate a significant degree of mixing in ichthyoplankton assemblages in this area.

The most distinct group in present study, discovered by both cluster and ordination analysis, was the one associated with antarctic waters and waters of Antarctic Polar Front. Three samples from this group were dominated by larvae of one myctophid *Krefftichthys anderssoni*. *Krefftichthys anderssoni* is abundant, circumglobally distributed myctophid with upper limiting temperature of 2.6-5.6 C (Andriashev, 1962; Hulley, 1981) and following broadly antarctic pattern of distribution (Hulley, 1981). McGinnis (1974) placed this species in his Antarctic- Antarctic Polar Front Complex. Other species grouped in this cluster, included larvae of *Electrona antarctica* and *Notolepis coatsi* -species quite typical for Antarctic waters. *Electrona antarctica* is probably the most common

myctophid occurring circumglobally south of the Antarctic Polar Front (Gon and Haemstra, 1990) and it is rather unusual that this abundant species was represented by such a small number of larvae. This might be attributed to the fact, that samples in the Antarctic Waters were represented by a single station 3003, taken on its northern boundary. *Notolepis coatsi* is the most typical paralepidid for Antarctic waters, distributed probably circumglobally in pelagic waters around Antarctica (Gon and Haemstra, 1990). Another typical antarctic species in collection included a single specimen of *Bathylagus antarcticus* caught on station 3005, situated in waters of Antarctic Front. Adults of this species are considered to be circumantarctic south of Antarctic Polar Front (Gon and Haemstra , 1990).

The classification results suggest important differences between subantarctic and Subtropical Convergence samples. Although no distinct groups in Subantarctic-Subtropical Convergence samples were obvious when all samples were ordinated, clear separation of these communities was attained removing the constrained effect of antarctic-antarctic polar front samples and subtropical sample. Zones of convergence (often termed transitional zones) between subpolar waters and the central gyres were reported to have unique distribution patterns of different organisms and constitute faunal discontinuities. Many investigators found, that some patterns of distribution are limited or concentrated in these boundary regions (Brinton, 1962; Johnson and Brinton, 1963; McGowan, 1971 and others). Numerous fish studies also supported this biogeographical division and many species were found to show the transitional pattern of distribution in Subtropical Convergences of both hemispheres (Gibbs, 1968; Krefft and Parin, 1972; McGinnis, 1974;

Bertelsen et al., 1976). In a very thorough and detailed analysis of southern myctophids to date, McGinnis (1974) reported a diverse assemblage of lanternfish species as restricted to the transitional region of the Subtropical Convergence in the southern hemisphere. Gibbs and McKinney (1988) described three species of the genus *Astronesthes* showing Subtropical Convergence pattern of distribution. Ichthyoplankton data can also be useful. Thus, recent study of leptocephalii assemblages by Miller and McCleave (1994) showed a significant role of Subtropical Convergence as zoogeographical division and in transport of leptocephalii between different water masses.

The present study support numerous studies on distribution of pelagic organisms in the STC, including study of Robertson et. al. (1978), who found good correspondence between mesopelagic communities and water masses associated with the Subtropical Convergence off the east coast of New Zealand. However, the role of Subtropical Convergence as a zoogeographical boundary is still not completely understood. As an example, recent study of distribution and community structure of midwater fishes by Young et. al. (1996) shows little difference in either abundance or community structure between the STC and the surrounding water masses. More studies are needed to resolve uncertainties with distribution of species in transitional regions of both hemispheres.

To summarize the results of classification and ordination it is relevant to outline here some characteristic species found in different water masses of the south western Pacific. The species occurring primarily in southern subantarctic waters included five *Protomyctophum* species, two species of *Gymnoscopelus*, three species of *Electrona* and *Symbolophorus sp. 2*. Other representatives included gempylid *Paradiplospinus*

antarcticus, scopelarchid *Bentalbella elongata* and unidentified bathylagid *Bathylagus sp.* Larvae of *Electrona subaspera,* as "indicator species" proposed by Andriashev (1962) were found only in subantarctic zone, which correspond well with known distribution of adults (Andriashev, 1962, McGinnis, 1974).

Among myctophid species found mostly in northern subantarctic waters and waters of Subtropical Convergence were *Protomyctophum chilensis*, four species of *Lampanyctus*, *Symbolophorus sp. 1*, scopelarchid *Scopelarchus guenteri* . Typical subtropical species found mostly within Subtropical Convergence waters were myctophids *Diogenichthys atlanticus*, *Ceratoscopelus warmingii*, *Loveina sp.*, *Diaphus ostenfeldi*, and two species of *Lampanyctus*, Other characteristic species included larvae of high-count species of *Astronesthes sp.*, found exclusively in the narrow band of Subtropical Convergence zone, thus providing some additional support for data published by Gibbs and McKenney (1988) on this kind of transitional distribution for three species of *Astronesthes*. Larvae of *Gonichthys barnesi* - the myctophid known to have excluively transitional pattern of distribution were found only in Subtropical Convergence waters. Other species found primarily in waters of Subtropical Convergence included *Scomberesox saurus* - indicator species for subtropical waters (Andriashev, 1962), gonostomatid *Vinciguerria attenuata*, exocoetid *Hirundichthys rondeletti*, evermannellid *Evermannella balbo.* Other species were represented by single specimens.

Sample 38 taken on the periphery of subtropical gyre was dominated by larvae of flying fish *Exocoetus obtusirostris,* and included larvae of some other exocoetids e.g.*Cypselurus sp., Prognichthys sp.*, oxyporamphid *Oxyporamphus micropteryx*, species

of chiasmodontids, and typical subtropical myctophid species *Ceratoscopelus warmingii, Diogenichthys atlanticus.*

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Appendix 1. Matrix of species rank-abundance (# of specimens/1000m^3) versus sample used in cluster and ordination analysis, Part1.

Species No.	Species / Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	*Bathylagus antarcticus*			0.02																
2	*Bathylagus sp. 1*	0.02		0.04	0.08	0.16	0.27	0.41		0.05	0.16	0.03								
3	*Dolichopteryx longipes*															0.05				
4	*Opisthoproctus soleatus*													0.05						
5	*Cyclotone spp.*				0.24	0.33	0.05	0.11	0.16	0.22	0.24	0.14		0.11	0.22	0.11	0.05	0.03		
6	*Danaphos oculatus*																			
7	*Diplophos rebainsi*													0.03						
8	*Argyropelecus hemigimnus*								1.08	0.59		0.03				0.03				
9	*Maurolicus sp.*																			
10	*Sternoptyx sp.*				0.06	0.02		0.05							0.03	0.03		0.05		
11	*Ichthyococcus sp.*																			
12	*Vinciguerria attenuata*																		0.35	0.22
13	*Vinciguerria nimbaria*																			
14	*Woodsia meiyerwaardeni*									0.05		0.03				0.03				
15	*Chauliodus sp.*																			

16	*Stomias spp.*				0.04	0.06				0.03	0.05	0.03							0.22	0.14
17	*Astronesthes sp.*																		1.08	0.08
18	*Bentalbella elongata*				0.02	0.03		0.03		0.03		0.03		0.03						
19	*Scopelarchus guenteri*												0.27	0.41	0.43	0.22	0.08	0.03	0.19	0.08
20	*Scopelarchus sp.*																			
21	*Scopelosaurus cf. herwigi*																	0.03		
22	*Notolepis coatsi*	0.33	0.16	0.12																
23	*Stemonosudis sp.*					0.04	0.03	0.03		0.08	0.03	0.03		0.08	0.05	0.03	0.05	0.03		0.03
24	*Macroparalepis sp.*																			
25	*Paralepididae spp.*																			
26	*Evermanella balbo*																			
27	*Ceratoscopelus warmingii*																		0.11	0.05
28	*Diaphus ostenfeldi*					0.14													0.54	0.51
29	*Diaphus sp.*																			0.05
30	*Diogenichthys atlanticus*																			
31	*Electrona antarctica*	0.04	0.06																	
32	*Electrona carlsbergi*				0.04	0.10		0.05												
33	*Electrona subaspera*					0.04	0.43	0.40	0.57	0.46	1.08	0.46	0.08	0.11	0.08					
34	*Electrona sp.1*														0.08	0.03				
35	*Electrona sp.2*					0.02	0.22	0.32	0.22	0.05	0.32	0.11	0.68	0.14		0.08				
36	*Gonichthys barnesi*																			
37	*Gymnoscopelus sp.1*				0.41	0.61	0.54	0.73	0.54	1.03	1.08	0.46	0.03	0.08						
38	*Gymnoscopelus sp.2*			0.10	0.10	0.31	0.35	0.32	0.41	0.27	0.16									

39	*Hygophum sp.*															0.03				
40	*Hygophum bruuni*							0.03	0.05	0.08	0.05							0.05		
41	*Hygophum reinhardi*																			
42	*Krefftichthys anderssoni*	3.47	0.33	0.20	0.02															
43	*Lampadena sp.*																			
44	*Lampanyctus sp.1*																		0.24	0.22
45	*Lampanyctus sp. 2*							0.03	0.05		0.19	0.05	0.03						0.08	0.08
46	*Lampanyctus sp.3*																			
47	*Lampanyctus sp.4*										0.11		0.03	0.08		0.05			0.35	0.49
48	*Lampanyctus sp.5*							0.05				0.03					0.03	0.05		
49	*Lampanyctus sp. 6*										0.05						0.08	0.14		
50	*Lampanyctus sp. 7*						0.16				0.08									
51	*Lampanyctus sp.8*																			
52	*Loveina sp.*																			0.05
53	*Myctophum phengodes*																			
54	*Protomyctophum bolini*				0.20	0.84		3.25	2.22	2.05	1.89	0.73	0.03	0.03	0.14	0.05		0.11		
55	*Protomyctophum chilensis*						0.11	0.22	0.27	0.46	1.62	0.31	0.03	0.03	0.32	0.19	0.41	0.22	0.27	0.19
56	*Protomyctophum normani*					0.10			0.11	0.16										
57	*Protomyctophum sp.1*				0.61	0.41	0.32	0.11	0.68		0.24	0.84	0.14							
58	*Protomyctophum sp.2*				0.06	0.16	0.16	0.41	0.08		0.14	0.16								
59	*Protomyctophum sp.3*						0.27	0.35	0.05											
60	*Protomyctophum sp.4*				0.02															
61	*Symbolophorus sp1.*																	0.03	0.81	0.73

62	*Symbolophorus sp2*						0.27	0.24	0.22	0.27	0.05									
63	*Lampris sp.*																			
64	*Scomberesox saurus*									0.05							8.95	12.0	3.78	4.92
65	*Dolopichthys longicornis*																			
66	*Melanocetus johnsoni*																			0.05
67	*Cypselurus sp.*																			
68	*Exocoetus obtusirostris*																			
69	*Hirundichthys rondeletti*																		0.22	0.14
70	*Prognichthys sp.*																			
71	*Oxyporamphus micropteryx*																			
72	*Acanthochaenus luetkeni*																			0.30
73	Melamphaeidae gen sp.					0.02	0.08	0.19	0.14	0.16	0.14	0.08		0.03		0.11	0.03	0.05		
74	Zeidae gen.sp.																			
75	*Epigonus sp*											0.03		0.03				0.08		0.08
76	Apogonidae gen sp.																			
77	*Chiasmodon sp.*																			
78	*Dysalotus sp.*																			
79	Bramidae gen sp.																			
80	*Caristius sp.*																			0.03
81	*Naucrates ductor*																			0.03
82	*Trachurus sp.*																			
83	*Paradiplospinus*					0.67	0.81	1.05	0.41	0.22	0.92	0.84		0.05	0.11	0.05		0.03		
84	Nomeidae gen sp.																			

Appendix 1. Matrix of species rank-abundance (# of specimens/1000m^3) versus sample used in cluster and ordination analysis, Part2.

Species No.	Species \ Sample	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	*Bathylagus antarcticus*																			
2	*Bathylagus sp.*																			
3	*Dolichopteryx longipes*								0.03											
4	*Opisthoproctus soleatus*																			
5	*Cyclotone spp.*	9.49	0.19	0.11	0.27	0.03	0.03	0.03	0.11										0.32	0.32
6	*Danaphos oculatus*		0.14																	
7	*Diplophos rebainsi*						0.03	0.08			0.16		0.03				0.03			
8	*Argyropelecus hemigimnus*																			
9	*Maurolicus sp.*															0.03				
10	*Sternoptyx sp.*		0.14						0.03											
11	*Ichthyococcus sp.*				0.08	0.05	0.05											0.03	0.03	
12	*Vinciguerria attenuata*	1.11	0.22	0.16	0.46	0.14	0.16	0.03			0.03		0.05					0.08	0.49	0.05
13	*Vinciguerria nimbaria*																			0.43
14	*Woodsia meyerwaardeni*																			
15	*Chauliodus sp.*																		0.11	

16	*Stomias spp.*	0.78	0.05	0.27	0.54	0.03	0.08						0.03		0.03		0.11			
17	*Astronesthes sp.*	0.51	0.11	0.03	0.05															
18	*Bentalbella elongata*																			
19	*Scopelarchus guenteri*	0.62	0.14	0.03	0.11	0.03	0.05	0.05	0.05	0.03	0.14						0.11		0.14	
20	*Sopelarchus sp.*																			0.05
21	*Scopelosaurus cf. herwigi*											0.05				0.16	0.14			
22	*Notolepis coatsi*																			
23	*Stemonosudis sp.*	0.03			0.19	0.27	0.27	0.3	0.03	0.03	0.16	0.03	0.43				0.08	0.11		
24	*Macroparalepis sp.*	0.08				0.03														
25	*Paralepididae spp.*		0.11	0.03																
26	*Evermanella balbo*		0.03		0.03														0.05	
27	*Ceratoscopelus warmingii*	0.92	1.57																0.22	0.30
28	*Diaphus ostenfeldi*			0.19	0.22		0.27												0.11	
29	*Diaphus sp.*	0.08		0.19	0.03															0.16
30	*Diogenichthys atlanticus*	0.08	0.19		0.16														0.11	1.73
31	*Electrona antarctica*																			
32	*Electrona carlsbergi*														0.08					
33	*Electrona subaspera*					0.05	0.14		0.03	0.03		0.14	1.08	0.24		0.62	1.11			
34	*Electrona sp.1*																			
35	*Electrona sp.2*													0.05	0.05		0.22			
36	*Gonichthys barnesi*				0.03	0.03													0.11	
37	*Gymnoscopelus sp.1*									0.03	0.68	0.03	0.38	0.57	0.11	1.14	0.73			

38	*Gymnoscopelus sp.2*													0.16	0.24	1.89				
39	*Hygophum sp.*			0.03							0.03								0.14	
40	*Hygophum bruuni*			0.05			0.08				0.11		0.05							
41	*Hygophum reinhardi*																			0.03
42	*Krefftichthys anderssoni*																			
43	*Lampadena sp.*										0.03									
44	*Lampanyctus sp.1*	0.16			0.05	0.22													0.35	
45	*Lampanyctus sp. 2*				0.33	0.22		0.03	0.03		0.03									
46	*Lampanyctus sp.3*		0.05		0.32															
47	*Lampanyctus sp.4*	0.27			0.05		0.51	0.24	0.05								0.05	0.11	0.16	
48	*Lampanyctus sp.5*			0.05		0.08	0.05	0.16		0.08	0.62	0.08	0.09			0.19	1.16			
49	*Lampanyctus sp. 6*						0.54	0.14	0.08			0.03								
50	*Lampanyctus sp. 7*						0.08				2.38	0.27	0.59				0.05	0.41		
51	*Lampanyctus sp.8*																0.27			
52	*Loveina sp.*	0.08																	0.03	
53	*Myctophum phengodes*	0.41		1.16	0.84														0.19	
54	*Protomyctophum bolini*								0.08	0.16		0.19	0.14	0.51	0.65	0.46				
55	*Protomyctophum chilensis*	0.05			0.03	0.11	0.03	0.16	0.03	0.16		0.05	0.41					0.38		
56	*Protomyctophum normani*								0.03			0.41	0.81	1.84	0.32	2.95	0.89			
57	*Protomyctophum sp.1*											0.27	0.24	1.27	0.43	0.24				
58	*Protomyctophum sp.2*		0.05									0.19	0.08	1.57	1.03	0.22	0.03			
59	*Protomyctophum sp.3*													0.11						

60	*Protomyctophum sp.4*															0.16	0.05			
61	*Symbolophorus sp1*	0.38	0.03	0.46	0.19		0.05	0.03			0.05		0.05	0.05			0.11	0.22	0.14	
62	*Symbolophorus sp2*									0.03	0.05	0.08	0.14	0.05		1.03	0.97	0.14		
63	*Lampris sp.*		0.03		0.03		0.03													
64	*Scomberesox saurus*	3.14		0.30	0.05	1.16	1.8			7.57	5.43									
65	*Dolopichthys longicornis*																			
66	*Melanocetus johnsoni*	0.03																	0.08	
67	*Cypselurus sp.*																			0.16
68	*Exocoetus obtusirostris*																			10.27
69	*Hirundichthys rondeletti*	0.30																		
70	*Prognichthys sp*																			
71	*Oxyporamphus micropteryx*																			0.41
72	*Acanthochaenus luetkeni*																			
73	Melamphaeidae gen sp.			0.05	0.05													0.11	0.19	0.08
74	Zeidae gen.sp.		0.03			0.03														
75	*Epigonus sp.*																			
76	Apogonidae gen sp.	0.05																	0.03	
77	*Chiasmodon sp.*																		0.03	0.03
78	*Dysalotus sp.*																			0.03
79	Bramidae gen sp.	0.03					0.03													
80	*Caristius sp.*	0.05																	0.03	
81	*Naucrates ductor*																			

82	*Trachurus sp.*						0.05										0.03				
83	*Paradiplospin antarcticus*									0.22	0.19	0.08	0.08			0.03	0.27				
84	Nomeidae gen. sp.																				0.03